EXPERIENCES
in
GENERAL SCIENCE

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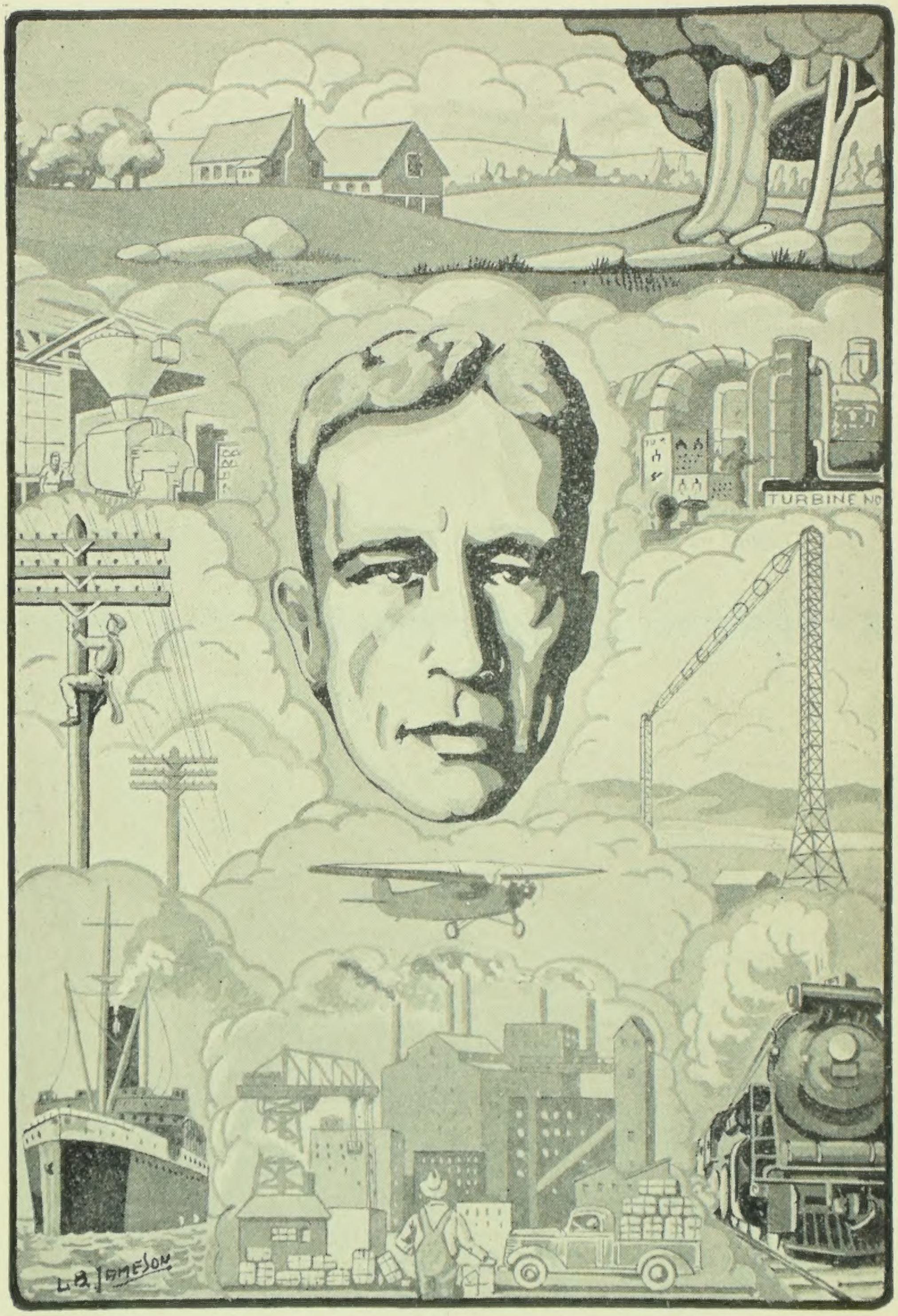

In your study of science you will learn something of your environment which year by year becomes more complex.

EXPERIENCES IN GENERAL SCIENCE

An Introductory Study of Our Environment

BY

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INTRODUCTION

Many of you have spent a holiday at one of the less frequented places on the shore of a lake. Wherever you turned, your eye rested on a delightful scene. You saw blue water pleasantly creased into glistening waves, boulders and rock, balsam fir, cedar, and white birch. The Indian of a thousand years ago must have gazed on an almost identical picture, his nostrils filled with the odours of evergreens and his ears with the song of a bird. Compare this with the view from a window in a city house. One looks out on brick houses and wooden garages, on lawns and flower beds, on an elm-lined asphalt street noisy with automobiles.

Civilized man is continually changing his surroundings. Sometimes the change is far from being an improvement. For instance, the thoughtless or ill-bred camper hacks down a tree as old as himself merely because his view is obscured, or leaves behind him a litter of papers, rags and empty cans. Fortunately, the change is often for the better. Rivers have been dammed to produce power needed in the home or factory. Forests have been replaced by fertile farms. Marshes have been drained to become the sites of cities, and water has been brought a hundred miles to quench the thirst of millions. Artificial waterways have been constructed and mountains have been pierced by tunnels to aid transportation. Harbours have been made, sometimes at enormous cost, in the most unlikely places.

Many once-dreaded diseases have been conquered by medical science; human suffering has been relieved and the span of life extended.

Practically every food plant has been modified to make it more fruitful or to render its product more palatable. The horticulturist is tireless in producing new varieties of flowers to adorn our gardens. Most of our domestic animals, through the agency of man's brain and hand, have departed far from the form and habits of their wild ancestors.

Weather and climate have not come under his control, but he is not baffled. He has changed his diet, clothing, and dwellings so that he may live at the equator or within the arctic circle. Snowshoes, fur coats, umbrellas, windshield wipers, artificial light, heating systems, refrigeration, humidification, and even "daylight saving" are but a few of the many more or less successful attempts to cope with adverse weather or climatic conditions.

Man has extended the range of his voice until it can be heard around the world. He has brought devices to the aid of his eyes so that the extremely small germ and the very remote star come into his vision, and he can examine a fractured bone without requiring the injured person to remove his clothes. He is not well fitted for movement in water, yet he can propel himself rapidly in the depths of the sea as well as on the surface. With no natural power of flight, he has conquered the air and can out-distance the swiftest bird.

Indeed, it would seem as if man is filled with a restless desire to change his surroundings, not only that they may more readily serve his needs, but also so that they may approach the ideal of beauty that his mind contains.

Everything that affects his existence, for example, land, water, air, climate, power, plants, animals, other human beings, and the heavenly bodies, make up man's environment. To have some knowledge of this environment, which, year by year, is becoming more and more complex, is both interesting and useful.

EXPERIENCES IN GENERAL SCIENCE

Courtesy of W. C. McCalla.

Fig. 1. Harvest sky in Alberta.

TOPIC I—INTRODUCTORY

UNIT 1. MAJOR STUDY: Science and the scientific method have made many useful contributions to modern living.

A. MINOR STUDY: Science is the systematic study of the things about us.

In one week cut out all the articles in a daily newspaper that you think relate to science. Mount these with care in a scrap book, leaving room for many similar clippings. Date each article and write under it the name of the newspaper from which you cut it. Here are a few sample headings taken from a newspaper:

1. "Tiny Animal Makes Starch."
2. "Birds Do More Good Than Harm Says the Expert."

3. "Four Are Crippled by Fungous Poison."
4. "82 Below Zero at 75,500 Feet."
5. "Thatcher Wheat First in Test."
6. "Barometers Hit New Low For America."
7. "Over-Cultivation Must Be Abolished."
8. "Crops Without Soil."
9. "How the Rocks Came to the Prairie."
10. "Fog Facts."

Of course you will find it difficult to understand everything in each article. Such understanding comes only after you have gained a fund of scientific knowledge that we speak of as "background". Boys and girls like to ask questions. Now we are going to try to answer some questions about science.

PROBLEM I: (a): Why do men study science?

You ask, "How am I going to obtain this scientific knowledge?" Have you ever seen:

1. a magnet pick up a steel pin?
2. the shadow cast by a stick placed in front of a source of light?
3. a fish develop from egg to adult?
4. fossils in limestone?
5. the small plant inside a bean seed?
6. a fog over a meadow in early morning?
7. a cow chewing the cud?
8. a fully developed American beauty rose?
9. a rainbow across the eastern sky?
10. the stars on a clear winter night?

The first step is to begin to ask questions about the things you see around you. We have come to know about our surroundings because we have been curious about the world in which we live—our environment. To gain what knowledge we have, has taken centuries of time. Many of our questions still remain unanswered.

PROBLEM I (b): How do scientific workers attempt to solve their problems?

Let us suppose that you have asked your teacher the question, "Why does cream form at the top of a bottle filled with whole milk?" If he is a wise teacher, he will say, "How can we find out?" Interest in a problem is at the beginning, not only of scientific thinking, but indeed of all reasoning.

When you have a problem to solve, you should learn as much as possible about it by observation and reading. This gathering of helpful facts is the second step. From your reading you will find out that whole milk contains droplets or globules of fat scattered throughout a watery liquid, and that cream is formed by the coming of most of these fat globules to the upper part of the liquid. The problem may be re-stated as follows: "Why do the fat globules, which at first were scattered throughout the milk, assemble at the upper part?"

Then you think about your problem. You recall familiar examples of objects rising to the top of liquids. For instance, you may hold a piece of cork under water, but when you remove your hand the cork bobs up. "Why did the cork come to the surface?" you ask yourself. Each cubic inch of cork is lighter than a cubic inch of water. The heavier water pushes up the cork. Is it possible that, volume for volume, cream is lighter than the watery liquid we call skim milk, and that the heavier skim milk pushes the lighter fat upwards?

We are supposing that you have suggested an answer to your question. The answer seems probable enough, *but it must be tested.* If your answer is the correct one, a quart of cream should weigh less than a quart of skim milk. Careful weighing shows that this is true. Hence, you have some support for your answer. Scientists apply many tests to their answers or 'guesses' before they regard them as being very probably true.

If a quart of cream does not weigh less than a quart of skim milk, you would have to suggest some other likely answer or answers and apply tests.

The following procedure will help you in solving problems which have excited your interest. Try to find answers for each of the following questions.

1. *Exactly, what do I want to find out?* (State your problem as precisely as you can.)

2. *What information have I that may be useful to me in seeking a solution for my problem?* (Assemble all the knowledge you have concerning the problem. Often, it is necessary to add to this knowledge by making observations, by reading, or by consulting with others.)

3. *What is the most likely solution of my problem?* (Think over the information you have assembled and give the most probable one of the different solutions that come to your mind.)

4. *How may I test the truth of the answer I have suggested?* (The answer suggested may not be the true one. Reason in this way: if my answer is the correct one, then something or other must be true. Now make some observations or perform experiments to find whether or not this 'something' is really true. *If you find that the 'something' is true, it does not prove that you have the correct solution of your problem; it makes its truth a little more probable.* Scientific workers are repeatedly testing the 'guesses' they make. The oftener one of these 'guesses' is upheld by tests, the more probable is its truth.

If your answer is not supported by the test, you must begin again. You must seek more information; you must give another likely answer and test it. Indeed, it is often necessary to go back to the beginning again and again.)

Compare the above procedure with that used in trying to discover why cream forms at the top of the milk.

A practical problem to solve.

In Southern Alberta it is commonly stated that rain follows a fog in exactly 90 days. How would you proceed in order to find out if this statement has any truth? Carry out your suggested procedure.

Exercises:

Study the following newspaper editorial from *The Calgary Herald*, July, 1938. Make an outline of how the scientist has approached this problem in his search for truth.

WHAT NATURE SHOWS US.

Two recent fatalities believed to be due to the infection of deer flies do not mean that every victim of this fly's bite will necessarily contract tularaemia. For to become a carrier of such disease germs—and every blood-sucking and carrion-feeding insect is a potential germ distributor, the deer fly must have been in direct contact with an animal afflicted with tularaemia. And deer flies may make a million meals and leave nothing but a painful swelling as the after effect of their bite.

Deer flies have recently claimed public attention on another score. A scientist, stating that he had clocked their speed of flight at the rate of four hundred yards a second, makes the assertion that they are the fastest flying insect; the fastest living creature if his calculations are correct. Such a contention appears an impossibility for, reduced to miles per hour, it would mean that the deer fly can fly at a speed of eight hundred miles an hour, a rate of travel greater than that of the waves of sound.

Criticising his theory, other scientists have pointed out that the deer fly travelling at such a speed would literally become embedded in the flesh of its victim like a bullet. That, in fact, it could overtake a shot fired from a hunter's gun; that at such a velocity, lacking streamlining in its blunt head, the air pressure of eight pounds per square inch would crush it to a pulp before it had progressed any perceptible distance.

Other objections have been raised. At one-tenth of such speed its flight would be invisible; its fragile wings would become frayed and useless, its energy unable to develop such quickness impossible even in the power of a modern engine or the propulsion of gunpowder exploding in a gun's bore.

The scientist who claimed this tremendous speed for the deer fly estimated its velocity by photographing the insect in flight and calculating the speed of the shutter. All it proves is that "scientists can make mistakes."

Without proof, the record of being the speediest insect still lies with the dragon-fly. It is also unusual in being one of the few creatures which can fly backwards and forwards with equal ease. It catches on the wing other flying insects. Its speed is very definitely known rarely to exceed thirty miles an hour.

What need a deer fly would have for so great a speed as has been recently claimed for it, is difficult to understand. Its food is the blood of slow-moving quadrupeds. But seemingly the best argument discounting its bullet-like velocity is the fact that the dragon-fly can capture it on the wing; a dragon-fly whose cruising speed is known not to exceed thirty miles per hour.

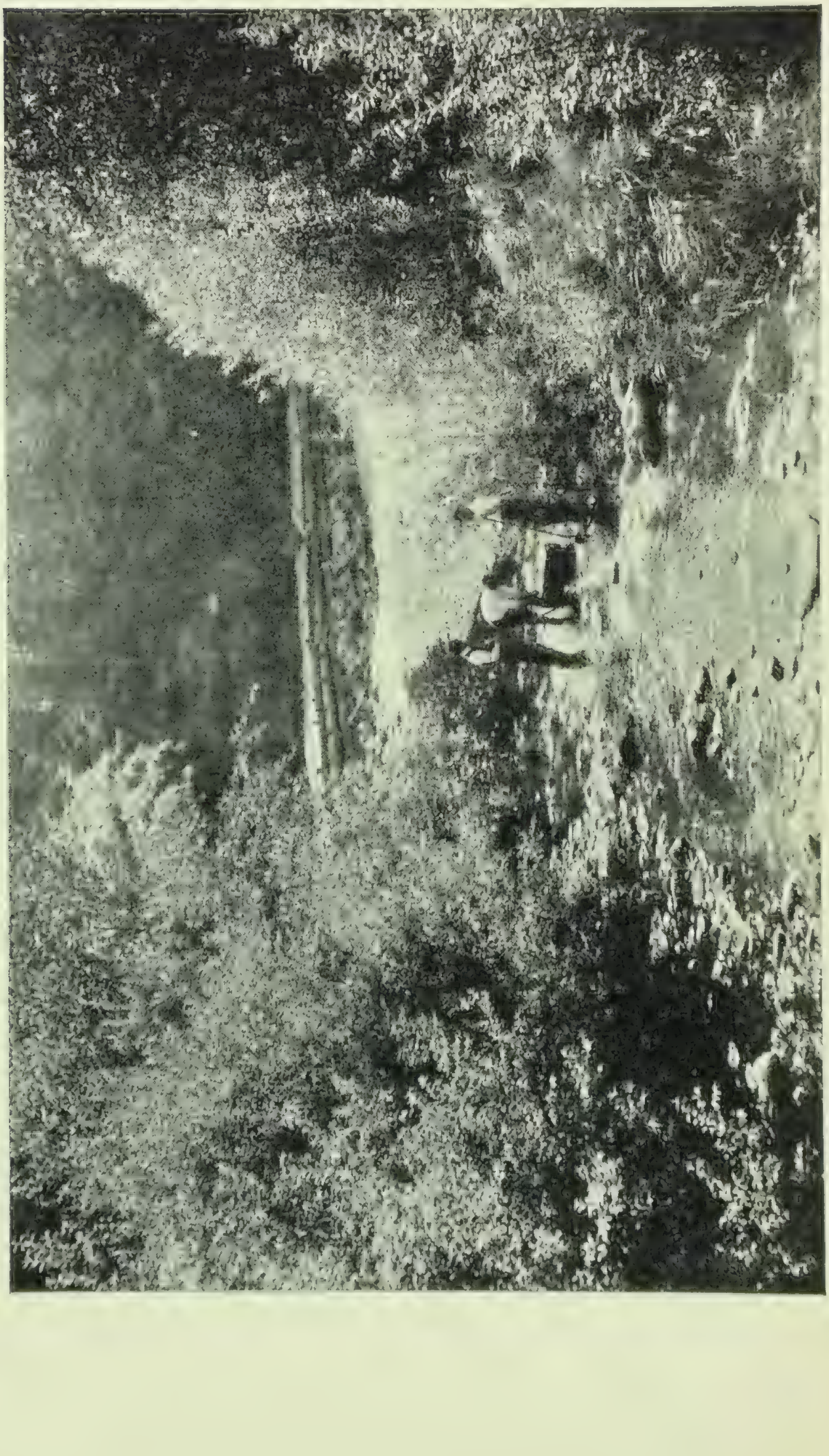


Fig. 2. Men altering their environment by 'planting' salmon eggs in a stream.

(Courtesy Dept. of Trade and Commerce, Ottawa.)

Exercises:

1. Read the introduction to this book very carefully. Attempt to answer the following question:
   In what ways is man able to adapt himself to (i) the weather; (ii) to modern inventions; (iii) to climate; (iv) to social life?
2. Make a list of any twenty factors in your immediate environment that seriously affect your life.
3. List ten differences between your environment when a baby and that of to-day.
4. Name ten important factors in your environment. Show the effect on your life if each of these factors is removed.
5. Indicate to what extent man has been able (i) to control disease; (ii) to control plants; (iii) to control animals; (iv) to control his environment through the use of machines.

Fig. 3. A spring pond has much to delight the observant one.

PROBLEM II: What procedure should be followed when performing and recording experimental work?

While you are studying science you will need to perform many experiments. It is wise to establish good habits in your work in order that you may get the best results. The following steps should prove of value to you.

1. *Objective:*

   Whenever you perform any experiment, you must have some aim in mind, some question to be answered, some problem to be solved.

2. *Materials:* (Those things like water, salt, soil or acid that you require in order to perform your experiment.)
   - (a) Those required for the particular experiment.
   - (b) Quantities to be used. (Follow instructions as to proportions and use the materials in moderation.)

3. *Apparatus:* (The other equipment necessary for performing the experiment.)
   - (a) Gather and set up the required apparatus. Have it well supported.
   - (b) Use the best equipment possible. Be careful in the handling of it.

4. *Procedure:*
   - (a) Work with a definite purpose in mind.
   - (b) Plan a definite sequence of steps in your experiment.
   - (c) Be cautious. Exercise good judgment.

5. *Observations:*
   - (a) Note all observations carefully and record them neatly.
   - (b) Attempt to account for each observation made.

6. *Conclusions:*
   - (a) Draw proper conclusions from your observations.
   - (b) Apply these conclusions to things about you.

Example:

1. *Objective.*
   To transfer air from one vessel to another.
2. *Materials.*
   A pitcher of cold water.
3. *Apparatus.*
   A Florence flask, thistle-tube, glass delivery tube, rubber stopper with two holes in it, rubber tubing, vessel (pneumatic tank), and gas-jar.
4. *Procedure.*

   The two pieces of apparatus were arranged as shown, and then connected by means of the rubber tubing.

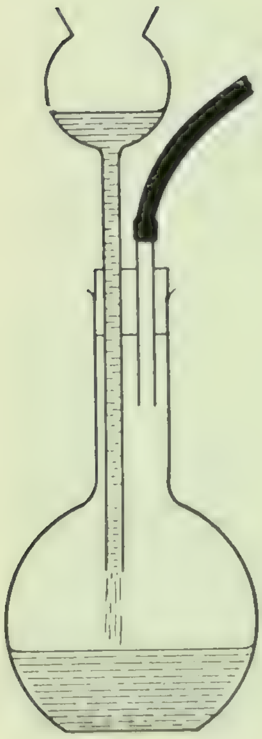


Fig. 4.

Some water was poured into the pneumatic trough. The gas-jar was filled with water and inverted in the tank. Then, water was poured into the thistle tube.

5. *Observations.*

Bubbles were observed to rise in the gas-jar. The water-level fell.

6. *Conclusion.*

Air may be transferred from one vessel to another in two steps: (1) by water displacing air and (2) by air displacing water.

Application: Gases insoluble in water may be collected by the displacement of water.

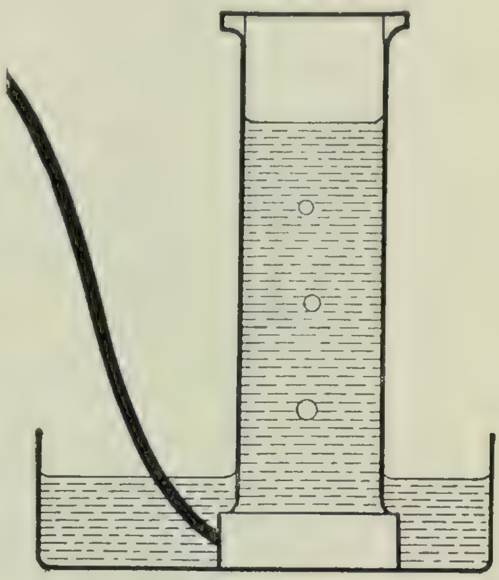


Fig. 5.

PROBLEM III: What are some important discoveries about our environment that have been made by the scientific method?

We may define the term environment as the sum of all those factors that surround and influence the lives of plants and animals. Our environment is said to be natural when it is untouched by man's hand. If the effect of man's hand is seen, for example, in cultivated plants and domesticated animals, in controlled waterfalls, in aids to transportation, in telephone, radio, and telegraph, the environment is said to be artificial.

The most important environmental factors that we shall study in the following pages of this book are water, air, food, light, heat, gravity, altitude and the earth's surface. Even the stars are part of man's environment, distant but valuable.

Before much progress was made in scientific thinking, men had to assume that things do not behave in a purely haphazard fashion, but that there is an orderliness in nature.

The aim of science is to discover the orderliness which is believed to be behind all happenings in nature.

When scientists find out a system or order according to which things behave, they are said to have discovered a *law*. Do not confuse this with the laws made by our parliaments.

Let us see how one of these laws was discovered by an early scientist who used the scientific method we have already discussed.

Courtesy of Brown Bros., Inc. N.Y.

Fig. 6. Sir Isaac Newton who discovered the law of gravity. In this illustration he is shown experimenting with light.

Air pressure decreases as the altitude is increased.

How many of you have ever wondered why you are able to "suck" soda water or pop through a straw? This problem aroused the curiosity of early scientists, although they used water instead of pop. They explained it by saying that nature did not permit empty spaces to exist. The problem was solved by Torricelli, a pupil of Galileo.

Lift pumps, commonly called 'suction' pumps were known

(Copyright, "The Wellcome Historical Magazine".)

William Gilbert was one of the most famous early scientists. He is shown giving Queen Elizabeth a lesson on the magnet.

in the 17th century. In a dry summer, the water in a well of a Duke of Tuscany fell 35 feet below the level of the ground. His lift pump had failed to work, so he sent for Galileo. This scientist already knew that air has weight. He now discovered that a 'suction' pump could not raise water to a height of 35 feet. He reasoned that the "resistance to a vacuum" was measured by a column of water less than 35 feet high. In 1643, Torricelli balanced a column of mercury and a column of air.

Torricelli's Experiment.

Torricelli took a glass tube 3 feet long, open at one end and closed at the other. He filled the tube with mercury (13½ times heavier than water), then, placing a finger over the open end he inverted it in the open vessel partly filled with mercury. When his finger was removed, the mercury in the tube fell until it was about 30 inches above the level of the mercury in the dish. This was the first barometer, so called by Torricelli because the word means pressure measurer. The vacuum at the top of the barometer tube is referred to as the Torricellian vacuum.

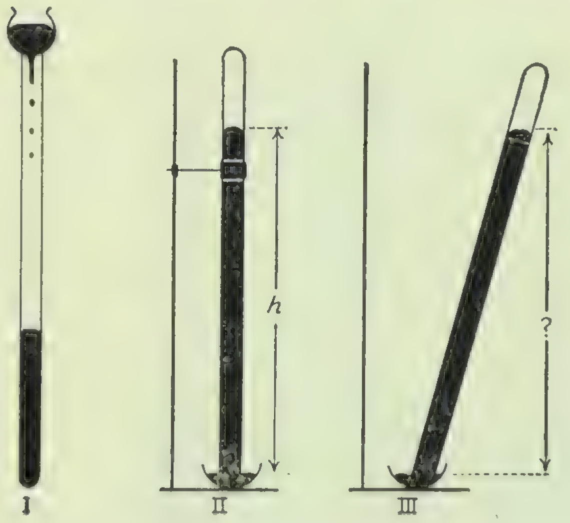


Fig. 7. An experiment dealing with air pressure in which the liquid metal mercury is used.

Scientists thus learned that water was pushed upwards in the pump by the pressure of the air on surrounding water.

Some years later, on the suggestion of Pascal, this new instrument was tried in measuring the heights of mountains. The fact that air pressure decreases as the altitude is increased was discovered.

Scientific method.

1. Curiosity aroused—The Duke of Tuscany's pump would not work.

2. Data—(a) Air has weight. (b) The "resistance which Nature offers to a vacuum" is measured by a column of water between 32 and 34 feet high.
3. Theory—Air has weight and therefore exerts a pressure.
4. Experiments—(a) The Torricellian tube. (b) Altitude tests.
5. Principle or Law—(a) The pressure of the air at sea level will support a column of mercury 30 inches high. (b) Air pressure decreases as the altitude is increased.

NOTE: A column of mercury 30 inches high and one square inch across weighs 14.7 pounds. Therefore, the pressure of the atmosphere at sea level is 14.7 pounds per square inch. By many tests it has been found that the mercury level in a barometer falls about 1 inch for each rise of 1,000 feet above sea level.

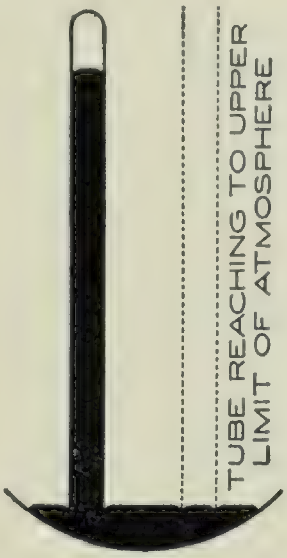


Fig. 8. The column of mercury is balanced by a column of air with the same cross-sectional area but of much greater height.

Exercises:

Ask your teacher to direct you to some books in which you can look up information on some of the following and note how the scientific mind worked when:

1. Sir Humphrey Davy invented the safety lamp for miners;
2. Guerickes experimented with air pressure using steel hemispheres;
3. Archimedes discovered why ships float on water;
4. William Harvey discovered that the blood circulates through the body;
5. Anton van Leeuwenhoek invented the microscope;
6. Thomas A. Edison invented the electric light bulb;
7. Wilhelm Konrad Roentgen discovered the X-ray;
8. Marconi invented his system of wireless telegraphy;
9. Alexander Graham Bell invented the telephone;
10. Monsieur and Madame Curie discovered radium.

B. MINOR STUDY: Science has made great contributions to the comfort and security of everyday life.

As we study, we note several stages in the growth of science. In an early stage, people observed a certain thing happen, and soon, a likely but untested story was offered in explanation. It was said that people who eat food cooked in aluminium dishes are liable to have stomach disorders. Nearly every household uses such utensils, so it was not difficult to build up quite a mass of apparent evidence. Cases which did not support the belief were overlooked. Science has now disproved this statement.

It is difficult to shake people's belief in such stories. For example, there are many superstitions about mad dogs. The old belief in mad-stones as a cure for mad dog bite still persists. Mad-stones, found in the stomach of a deer or a cow, were applied to the wound. Also, it was believed that a hair of the dog that bit you would, if applied to the wound, effect a cure. Men rushed to kill a mad dog that had bitten a child, in the belief that hydrophobia could thus be prevented. Science fights such beliefs by proving conclusively that they are wrong, that there can be no possible connection between the result and the supposed cause. This is done by experimentation.

Once truths have been discovered, they are expressed in the simplest language possible, as principles or laws. By a correct interpretation of a principle or law, man is able to predict. The fulfilment of the prophecy of an eclipse of the moon or sun, or the appearance of a comet, indicates the probable truth of the law upon which the prophecy was based.

PROBLEM I: **How has science helped to overcome disease?**

Among uncivilized peoples sickness is attributed to witchcraft or to supernatural causes. Evil spirits inhabit the body of the patient. The witch doctor or medicine man is called to drive out the demon by making it so uncomfortable that it will leave. This is accomplished by noise, odour, or by some form of trickery.

This belief in evil spirits inhabiting the bodies of people, goes back to Biblical days. In the middle ages, it was believed that disease was caused by these evil spirits at night. To prevent disease, all doors and windows were closed tightly at sundown. Superstitions continued until man made scientific discoveries about the real cause of disease.

People are slow to accept advances in any branch of science. Much fakery was found in the introductions of 'cure-alls'. Besides delaying diagnosis of disease by a qualified doctor, the medicines contained harmful drugs or alcohol. Mothers "soothed" their babies to sleep with syrups that contained habit-forming drugs.

Exercises: Study the content of the following paragraph from "Men of Mercy" by Paul de Kruif.

"Hardly a hundred years have passed since our searchers began to read in earnest the book of nature. In that moment of history what they've already learned has stretched the average human life span from thirty-five years to sixty. But who has dared record the cost of winning this little life-giving understanding? Who has told all the truth of fatal mistakes, false hopes aroused, pain endured, blood spilled, the toll of life of animals and men sacrificed to bring this little triumph over death?"

1. What is meant by the average human life span?
   NOTE: These results are really obtained because fewer people die in infancy.
2. Read "Microbe Hunter" by Paul de Kruif, and be able to tell some of the stories related by this writer.
3. Can you justify animal experimentation? You may be interested in reading "Men of Mercy" by Paul de Kruif. He calls men who experiment with animals "men of mercy". Why?

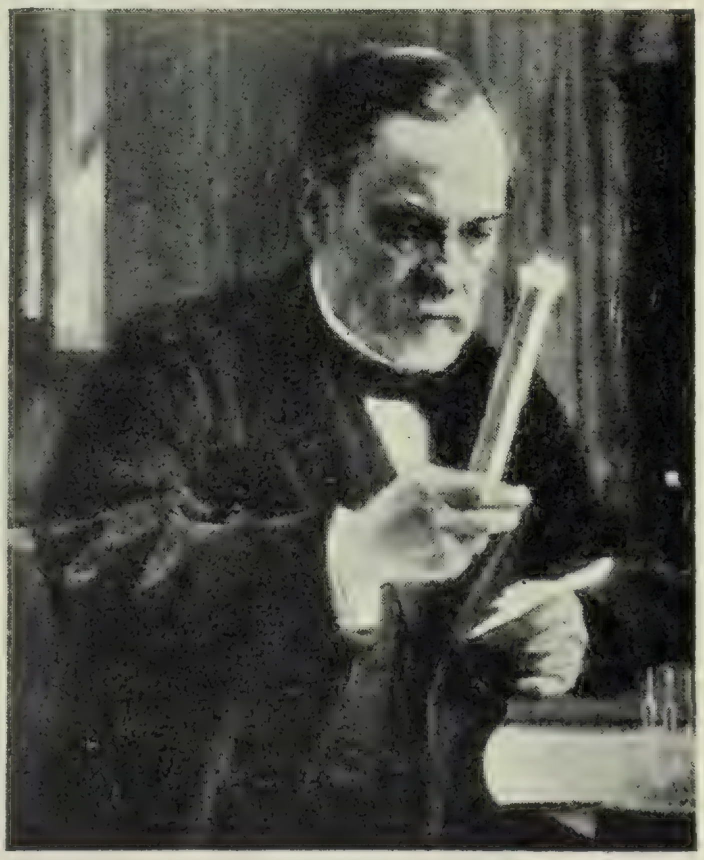


Fig. 9. Louis Pasteur.

In Shakespeare's day, the common cure for disease was to bleed the patient. The barber was the surgeon. The patient was cut and allowed to bleed. No attempt was made to sterilize the instrument used, consequently many cases of poisoning occurred. The present barber's sign or pole reminds us of this operation. The red strip is a symbol of the blood taken, the white, of the bandages used, and the ball on the top, of the basin used to catch the blood. Soon, horse leeches were imported from Belgium to England for this purpose and the surgeon became known as a "leech". The whole country was overrun by quacks.

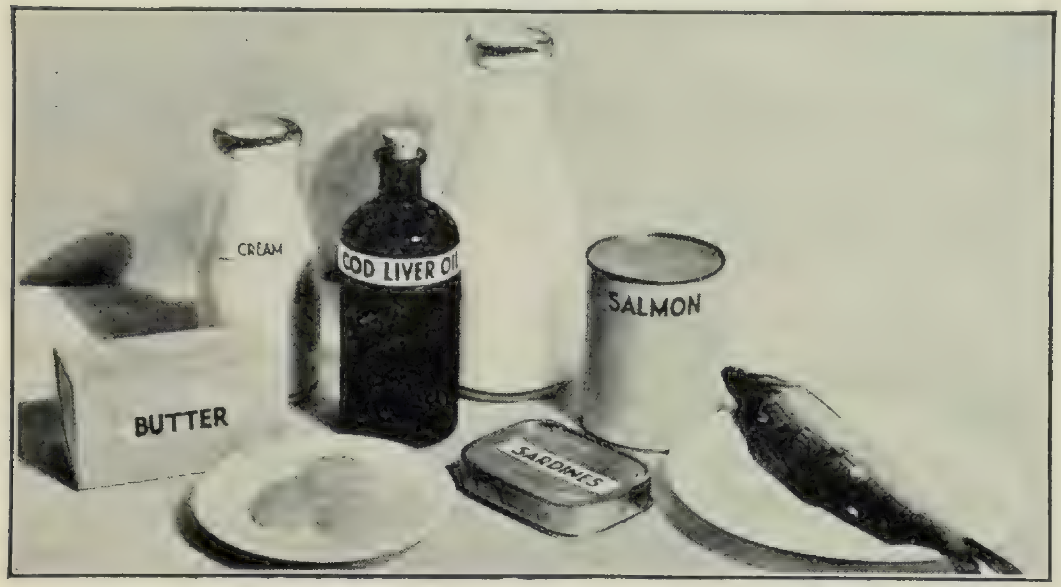
Courtesy of Brown Bros., Inc. N.Y.

Fig. 10. Prof. Robert Koch.

Note: The leech is still used by doctors in the treatment of bruises.

Some seventy years ago Louis Pasteur proved that microbes spoiled wines and sickened silkworms He thought that it might be possible to attack these germs. Joseph Lister was impressed and in his surgery dipped his silk thread or catgut into carbolic acid to destroy any microbes. Morton's pain-killing ether aided the surgeon in his operations. With the aid of ether and microbe-free instruments, men began to perform previously unheard of feats of surgery. The discovery of the X-ray by Roentgen allowed them to make surer diagnosis. The preparation of radium by the Curies brought new hope to people with cancerous growths. Dr. (now Sir Frederick) Banting, through the discovery of insulin did much to check the ravages of diabetes. Now "insulin shock" is being tried as a remedy for mental ailments.

Foods that Supply Vitamin D



(Courtesy of the U. S. Bur. of Home Economics.)

Fig. 11.

Microbe hunters, such as Robert Koch, working with deadly organisms, identified the microscopic causes of tuberculosis, diptheria, smallpox, cholera, yellow fever, and other diseases. Antitoxines for diphtheria, vaccination for smallpox, serums for colds, scarlet fever and many other ailments came as the result of constant experimentation.

Searchers turned their eyes to diet deficiencies. The scourge, scurvy, yielded to a diet of fresh fruits or vegetables. To-day we speak familiarly about vitamins A, B, C, D, E and G and link certain troubles with the lack of each in the diet. Gland secretions and their influence on human health have also been studied by research workers. Even the high school graduate has heard of chemical messengers or hormones and their function in governing the human body.

In short, much progress has been made in conquering diseases. Many major problems still remain to be solved.

Exercises:

1. Study the following columns carefully and learn all you can about each disease listed.

Conquered	*Almost Conquered*	*Progress*
Smallpox	Pneumonia	Insanity
Diphtheria	Tuberculosis	Cancer
Typhoid fever	Scarlet fever	Common cold
Malaria		Infantile paralysis
Yellow Jack		
Anthrax		
Rabies		
Pellagra		
Hog cholera		
Social disease		

   a. Can you add any other names to these columns?
   b. Read the story of the conquering of Yellow Jack. Note how the building of the Panama Canal was dependent on this victory.

2. Find out the difference between inoculation and vaccination.
3. How are vaccines and serums prepared?
4. Look up the meaning of the term virus.

Science from *The Children's Newspaper.*

THE CAPTAIN'S MUSTARD AND CRESS. A LITTLE CHAPTER OF ARCTIC EXPLORATION

An interesting and curious discovery comes into news this week:

Pressed between pages of an old book about Admiral Sir Edward Parry, who commanded five expeditions to the Arctic, a bit of cress was found.

It is the most historic and oldest bit of cress in the world, and was grown more than a hundred years ago on Winter Island in the Arctic. The story of how the cress came to be grown so far north, nearer to the Pole than any had been grown before, is one of the small romances of Arctic exploration.

The Sacks of Earth

Captain Edward Parry, who afterwards started out from Spitsbergen to reach the North Pole by sledge, and failed, was sent to find the North-West Passage in 1821. The ships with him were the *Fury* and the *Heola*. While the ships were waiting at Kirkwall in the Orkneys a boat came off to Parry's own ship, the *Fury*, with some sacks full of earth.

The ship's carpenter, an Aberdeen man, could hardly believe his eyes. What, he asked, could be the use of these? His mate soothingly replied that they were captain's orders, and depend on it, the captain had something in his head. The carpenter grudgingly stowed the sacks away, but throughout the voyage to the Arctic their presence irked him, and one day he ordered his mate to throw them overboard. The captain, he thought, would by now have forgotten his fancy. The carpenter's mate thought otherwise, and, instead of throwing the sacks overboard, prudently removed them to a safe place where the carpenter would not see them. He was right. When they came to Winter Harbour, where the *Fury* and the *Heola* were frozen in, Parry ordered the carpenter to make some long narrow boxes. This done, the captain asked for the sacks of earth.

The dumfounded Scot came down to his mate crestfallen and anxious. What was to be done now, he asked. The captain wanted the sacks they had thrown overboard!

It was the hour of his mate's triumph. The sacks, he said, had not gone overboard, and he produced them.

The Value of Fresh Food

Not only the carpenter but all the crew had reason to be grateful for his mate's foresight. In the narrow boxes of earth Parry sowed his mustard and cress, and these handy vegetables so helped him in keeping off scurvy, the scourge of polar exploration in those days, that his crews were kept in better health than ever before.

This ancient brown scrap of cress, which came to light again after more than 110 years, is a bit of science as well as a bit of history. It helped to prove the truth of what Captain James Cook had found by experiment many years before, that fresh food and vegetables keep sickness at bay. They contain what we now know as the necessary vitamins.

PROBLEM II: How has science helped to overcome fear and superstition?

Fear is often the cause of lack of progress. The "Dark Ages" were ages of superstition. During them, man was greatly afraid of the unknown. To some extent this fear kept him from trying to learn more about unfamiliar things. Until Columbus sailed westward, the thought of a flat world made sailors fear to approach the edge. If man's curiosity did make him attempt to penetrate the unknown, it was to invent some explanation that he frequently did not try to verify.

The scientific attitude substitutes for fear the attitude of curious investigation. The scientist searches for evidence and applies scientific judgment to his investigations. It would indeed be a strange idea of a Providence, that would create in us the power to reason and yet let such minor happenings as the following affect our lives seriously:

A. (1) To break a looking-glass; (2) to see a black cat cross the road in front of you (3) to walk under a ladder; (4) to put up an umbrella in a house; (5) to start a journey on Friday, especially if it be the 13th day of the month.

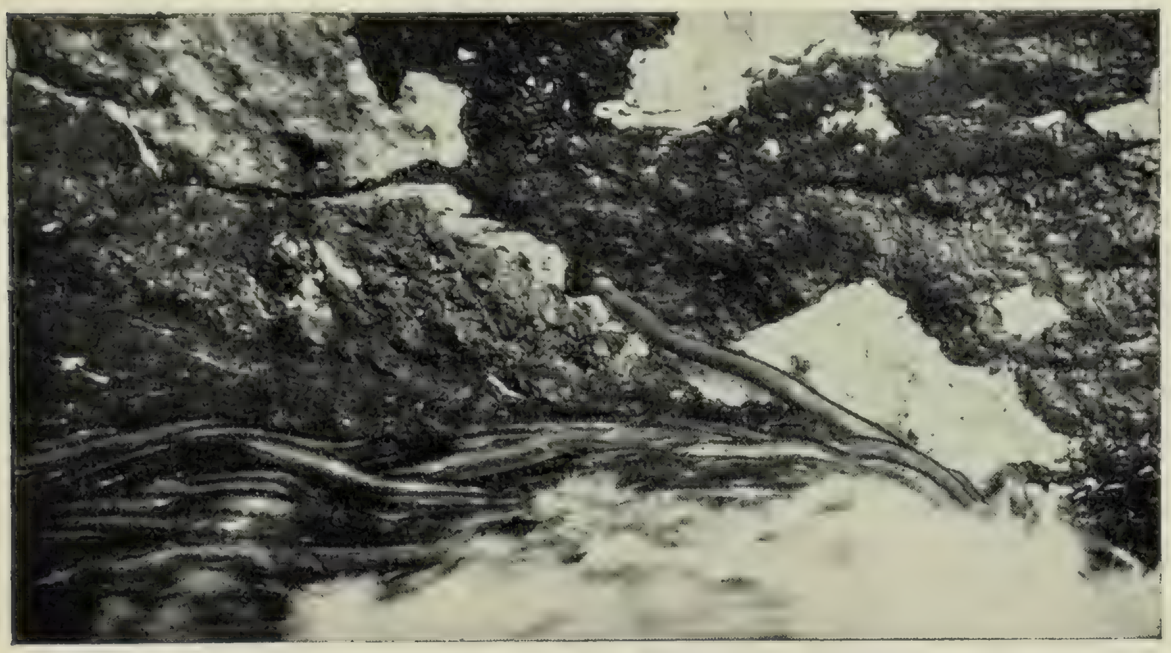
B. (1) To find a four-leafed clover; (2) to find a horseshoe; (3) to carry a rabbit's foot in your pocket; (4) to carry a luck-penny; (5) to see the new moon over your left shoulder if you have money in your pocket.

Exercises:

1. What evidence would any sensible person require before believing a well-known superstition?
2. Name several superstitions commonly believed by people who have not the scientific outlook.
3. " . . . . *where ignorance is bliss,*
   'Tis folly to be wise."
   What is the scientific attitude towards such a statement?

PROBLEM III: Have weights and measures played a part in the development of science?

Scientists such as Galileo and Newton found a need for measuring things other than articles of trade. Measurements became the very foundation of the work of the scientist especially after the beginning of the 18th century. Men began to measure things that had never been measured before—the weight of the air, the speed of light, gravitational force, friction, power and such. The units used had to be widely accepted. Standards were established and some of them are carefully preserved in such centres as the International Bureau of Weights and Measures near Paris. The Metric System of measurement has been accepted by scientists the world over.



(*Courtesy Nat. Museum of Canada.*)

Fig. 12. Eels moving downstream on their way to the spawning ground between Bermuda and the Leeward Islands.

As an example of how the scientific method has been applied through measurement, consider the mystery of the Atlantic eel. To discover the breeding place of this fish, scientists proceeded as follows:

Curiosity—No young eels were ever found in the rivers of the Atlantic coast.

Theory—Eels went out into the ocean to lay their eggs.

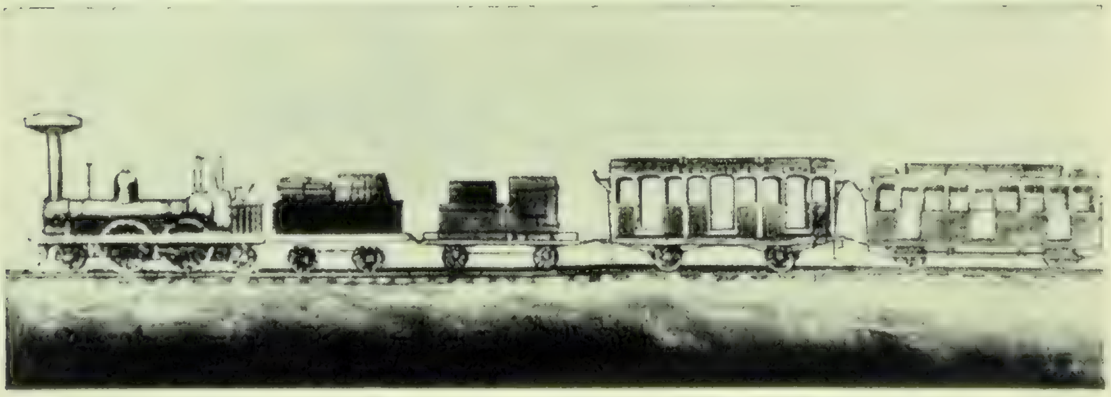
Experiment—Eels were gathered from many places in the ocean and were measured carefully. Hundreds of measurements were made and resulted in the discovery that eels decreased in size as the Sargasso Sea was approached from any direction.

Conclusion—Atlantic eels probably breed in the Sargasso Sea.

PROBLEM IV: How has science improved transportation?

NOTE: The word "Transportation" means the carrying of passengers and freight from place to place.

It is said that "necessity is the mother of invention." Man's most useful invention is believed to be the wheel. Think of the many ways in which travellers depend upon wheels. At first, wheels were used as rollers in moving weights. Next, rollers were fastened to a sledge by means of a kind of axle. Then man discovered that when the axle was fastened to the body at a single point, the centre, it was easier to make a turn. Carts could now be steered. The first wheels were pieces of tree trunks. Unfortunately, they broke easily. Spokes radiating from a central hub remedied this defect and permitted a lighter wheel to be used. Iron rims made the wheel wear longer. Later, solid rubber tires were used, to be replaced to-day by pneumatic tires. The use of lubricants to decrease friction was another important advance in the science of transportation.

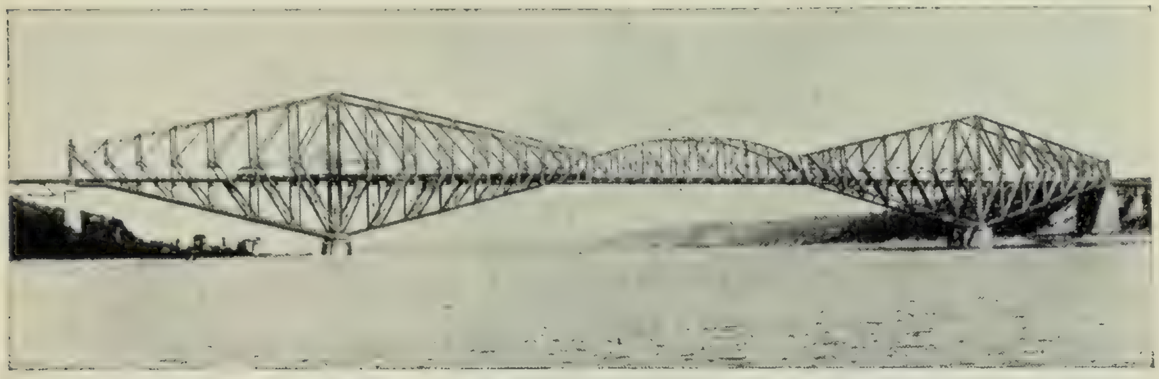


(*From "Sixty Years of Canadian Progress"* 1867-1927. *King's Printer, Ottawa,* 1927.)

Fig. 13. The first steam railway train in Canada, 1837.

In land transportation, various means have been used to pull, push, or propel vehicles. Dogs are employed in the north lands. Oxen, mules, horses, and even man power have been used down through the ages. Steam- and now gasoline- or oil-engines have largely replaced living creatures.

These vehicles had to have roads over which to run. It was necessary to span rivers by bridges or underwater tunnels. Mountains were conquered by means of tunnels, or by zigzag paths that utilized the principle of the inclined plane. Thus we find the scientist, that key-man of modern progress, at work. Roads progressed from the wagon trail to the modern cement highway. The modern railway with its guard rails, safety signals, and stream-lined trains is made possible by constant advancement along scientific lines.



(*From "Sixty Years of Canadian Progress"* 1867-1927. *King's Printer, Ottawa,* 1927.)

Fig. 14. The Quebec bridge—a link in the Canadian Government Railway System.

Travel by water began when man learned how to make use of a floating log. He built rafts on which to transport his goods. Then came the boat or barge stage. In propelling the boat, advance was made from the pole stage through the paddle, oar, sail, and paddle-wheel to the screw. To-day we have boats driven by steam-, gasoline- and oil-engines. The wind is still used as a propelling agent but to a limited extent.

For centuries men dreamed of flying. This dream was realized when the Montgolfier brothers in France built their first "smoke" balloon. Probably, they did not know that hot air is lighter than cold air, but thought that there was something peculiar about the smoke that made it rise. When men learned that certain gases are lighter than air, they began to fill the bags with hydrogen and later with helium, both of which gases are lighter than air. They controlled the ascent by carrying bags of sand as ballast. Steerable or dirigible airships came into use when men employed engines to propel balloons.

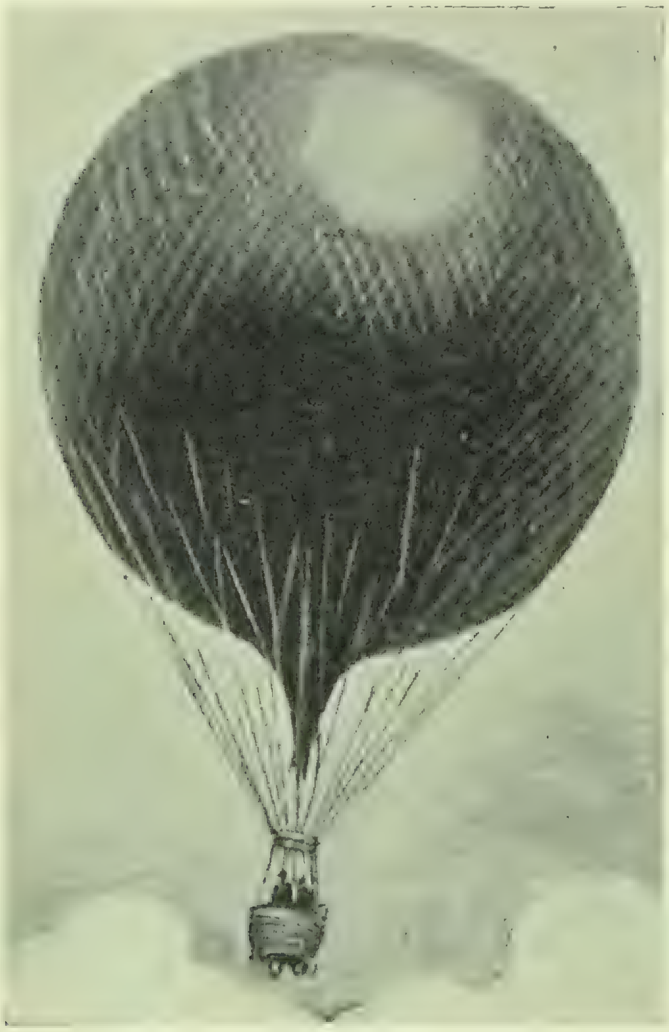


Fig. 15. The balloon rises rapidly, above the people, above the trees, high into the air, until we see it in all its beauty.

When men learned that the wings of their aeroplanes must be rounded on top and bottom, like those of a bird, they discovered the first real secret of flight. They found that to keep an aeroplane from falling there must be (1) an engine to keep the propeller revolving, and (2) a pressure of the air upon its planes or wings. It was learned that the curved shape of the wing forces the air past it in such a way that the upward pressure of the air on the under surface of the wing is greater than the downward pressure on the upper surface. In every aeroplane, from the first Wright biplane driven by an engine to the Clipper ships, you may discover the handiwork of the scientist. The Trans-Canada fleet of planes which began to carry mail, express, and passengers in October, 1938, is Canada's latest contribution to aviation.

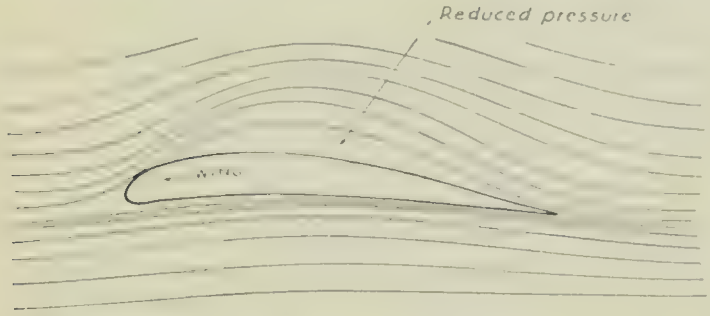


Fig. 16. The downward pressure on the upper side of the wing is less than the upward pressure on the lower side.

Exercises:

1. Find in a reference book pictures of the following forms of vehicles: (a) the Indian travois, (b) Cugnot's steam locomotive, (c) the sedan chair, (d) a Red River cart (e) a covered wagon or prairie schooner, (f) a jinrikisha of Japan, (g) an Eskimo dog team and sledge, (h) a jaunting car in Ireland, (i) a stagecoach, (j) an Egyptian chariot, (k) an omnibus, (l) Stephenson's locomotive, "The Rocket", (m) a treadmill train, (n) a Chinese sampan.
2. Discuss the relative importance of steam trains, electric trains, motor buses, and aeroplanes for the transporting of mail, express, freight and passengers.
3. "*For I dipt into the future, far as human eye could see,*
   Saw the Vision of the world, and all the wonders that would be;
   Saw the heavens fill with commerce, argosies of magic sails,
   Pilots of the purple twilight, dropping down with costly bales."
   Date—1886.

Tennyson lived before the age of modern transportation. Was his vision prophetic? What is your vision of transportation twenty-five years hence?

PROBLEM V: What has the scientist contributed to the improvement of communication?

Speech is the basis of all human communication. The scientist, through electrical and other devices, has enabled the partly deaf to hear again with ease. By improving the sound properties of buildings and the use of speaking tubes, he has extended the range of man's voice. He has made this range world wide by the invention of the telephone and the radio.

There was little progress in the world until the thoughts of men could be preserved by writing. The discovery of printing made information available to the masses. Newspapers, the radio, and good libraries have spread scientific knowledge to all classes of people.

In business, such machines as the typewriter, the mimeograph, and the dictaphone play an important part in communication. Modern business depends for its very existence on the telephone and telegraph. Air mail has speeded-up correspondence by letter.

The laying of the trans-oceanic cables linked the continents together by telegraph, so that to-day messages and pictures may be sent to any part of the world. The discovery of the Marconi beam enables the human voice to be carried to any part of the world. Television is only in its infancy, but, in the next few years, a rapid development is likely. In most fields of endeavour, first words rather than last words are being spoken. What of the future of communication? Shall we ever have an international language to make communication still easier?

Exercises:

1. In a history of England, read the story of the beginning of printing in England by William Caxton, 1476.
2. Write a short account of the laying of the trans-Atlantic cable.
3. Tell about important broadcasts that you have heard from a continent other than North America.
4. Describe a dictaphone and state its uses in a business office.
5. Read about the lives of Alexander Graham Bell and Samuel F. B. Morse. State what each contributed to the advancement of communication.
6. What was Guglielmo Marconi's contribution to the advancement of communication?

The Scope of Communication.

The Spoken Word

Normal speech
Whisper
Shout (across valley, over water)
Megaphone
Runners (Greek, Indian)
Relayed message
Messengers (on horseback, etc.)

Speaking tube
Town crier
Travelling poets
Travelling minstrels

Lip reading

Messages by Signals

Beacon fires
Smoke signals (Indian)
Drums, gongs, hollow logs
Flag signals
Flares
Rockets
Signal cartridges
Searchlight
Semaphore
Heliograph
Coloured lights
Gestures

The Written Message

Picture writing (Egyptians)
Written messages carried by.
  Runners
  Carrier pigeons
  Falcon
  Gray goose (China)
  Dogs
  Rockets
  Projectiles
  Trains
  Dog or reindeer teams
  Pony express
  Stagecoach
  Sailing vessels
  Steamboats
  Aircraft
  Motor car, truck, bus

Printed Communications

Newspapers
Magazines
Books
Billboards
Signs
Advertisements and showcards
Posters
Menu cards
Memorials
Greeting cards
Mottoes
Raised type (for blind)

Communication Using Electrical Appliances

Telegraph
Telephone systems
Wireless telegraphy
Radio (Long and short wave)
  (International hook-up)
Telotype
Television
Public address systems
Motion pictures and sound effects
Audiophone

Communication by Special Mechanical Devices

Phonograph
Mimeograph
Dictograph
Typewriters
Aeroplanes (sky writing)

Secret Communications
- Secret codes
- Secret gestures and signs
- Invisible inks

NOTE: Attempt a similar organization for the scope of transportation.

ENRICHMENT SECTION, NUMBER 1.

The units in which noise is measured.

A decibel is a measure of the intensity or loudness of sound. The lowest audible whisper is taken as the basis. The following scale gives some relative ratings for the loudness of sounds.

130 decibels	Pneumatic rock drill (threshold of pain).
120	Automobile horn or aeroplane motor.
110	Punch press or thunder.
100	Boiler factory or elevated train.
90	Heavy street traffic.
80	Loud music or ordinary street traffic.
70	Typewriter.
60	Ordinary conversation.
50	Noise of average office or of automobile running quietly.
40	Quiet office.
30	Average home.
20	Average whisper.
10	Rustle of leaves.
0	Threshold of sound (just audible).

NOTE: Sounds of 10 decibels are ten times louder than those of 0 decibels; those of 20 decibels are one hundred times louder; those of 30 decibels are one thousand times louder, etcetera.

The hairlike living cells of the cochlea of the ear are injured by too loud sounds and partial or complete deafness results. The New York State Department of Labour recently made a survey of 1,040 workers in noisy industries and not only found that deafness was more common in noiser industries but that it increased with years of exposure.

At Colgate University it was proved that a noise of 60 decibels or greater, actually slowed down the digestive contractions of the stomach; 60 decibels reduced the flow of saliva 44 per cent.

It has been found that a reduction of noise from 45 to 35 decibles was followed by an increase of 12 per cent in the output of office workers. When the noise in the telephone room of a telegraph company was reduced from 50 to 30 decibles, there were 45 per cent fewer errors made. This resulted in a 3 per cent drop in costs.

Exercises:

1. Have you a quiet place in which to study? Eliminate as much noise as possible during your hours of study.
2. Try to estimate school and home noises in terms of decibels.
3. Examine rooms such as libraries and radio broadcasting studios, and note the effect of carpets, curtains, rubber mats, etc., on the noises produced.

PROBLEM VI: What has science contributed to the lighting of our homes and cities?

In ancient times, man believed that the eye sent out some kind of ray which touched the thing he was looking at and so he was able to see the object. To-day we know that we see things because rays of light come from the object and enter our eyes forming an image on the retina of the eye. This image is translated to the brain by means of the optic nerve.

Fig. 17. The human eye.

Much of the light in our world comes directly from the sun, but at night and in dark rooms during the day, we must use artificial light.

Firelight is the oldest artificial light. A faggot torch was the first portable lamp. Open grease lamps were soon replaced by candles when men learned the use of a wick. Candles were made of tallow, and besides lighting the home, were used as clocks in the days of Alfred the Great. Candles are still employed but are now made of paraffin. However, they provide very little light, and in 1802 William Murdock introduced gas lighting. Kerosene lamps came into use about 1860 when the scientist learned how to break up crude petroleum by distillation. Edison gave us the first electric bulb in 1879.

(Courtesy of Can. General Electric Corporation.)

Fig. 18. Electric lighting and floodlight effects.

We live in an age of lamps. The electric lamp in our homes, the searchlight on land and sea, the lamp in the lighthouse, the headlight on the locomotive and automobile, the automatic coloured lights at our street and road intersections—all are marvels of our time. Man lights his stadium and plays baseball and football under flood-lights. Neon lights have been added to give brilliance and colour to our advertising.

Exercises:

1. Make a drawing of the human eye and name the various parts shown.
2. Describe an experiment to show that light travels in straight lines.
3. What happens when a piece of rough, white paper is held in a beam of sunlight entering a darkened room through a slit in the blind? Replace the paper with a looking glass and observe what occurs. Replace the looking glass with a glass prism and note the results.
4. Discuss the lighting of your school.
5. Note various ways in which we light our homes and public buildings.
6. Discover as much as you can about neon signs.

PROBLEM VII: How has science improved the heating of our homes and public buildings?

Primitive man heated his cave or dwelling by means of a bonfire placed at the entrance. Then, the fire was brought inside and an opening was made in the roof to allow the smoke to escape. The fireplace with its chimney was a vast improvement on the open fire. Iron stoves came into use in the 15th century. People in the

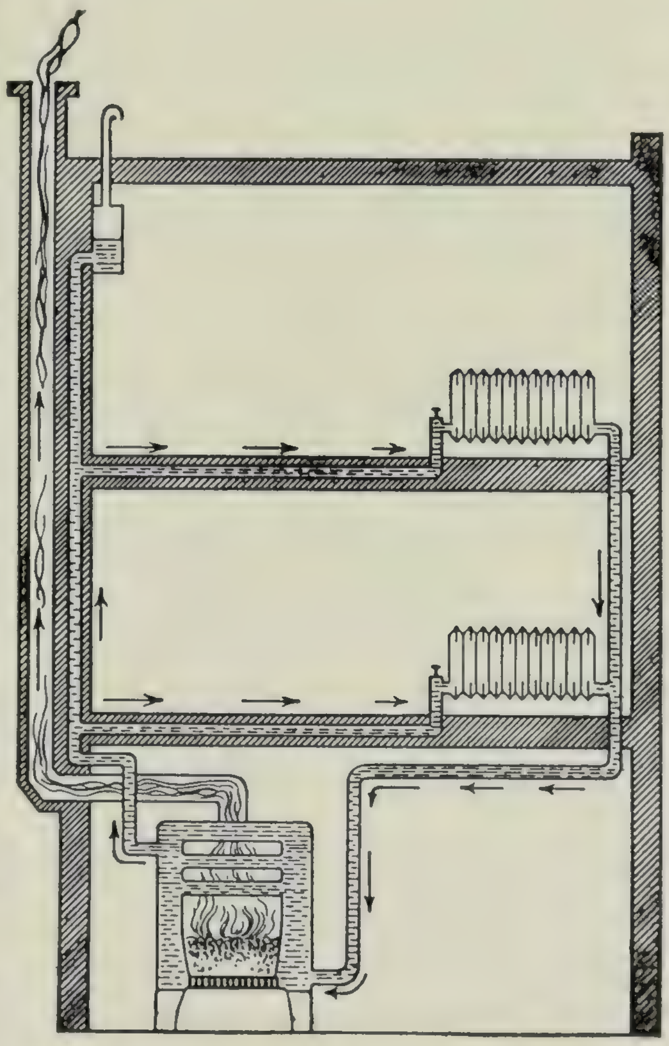


Fig. 19. A hot water heating system.

18th century heated their homes with a combination of fireplace and stove.

As buildings increased in size, these methods were wholly unsatisfactory. Men began to think of central plants that would heat the farthest corners of the building. They learned that heat might be carried from this heating plant by means of hot air, hot water or steam. To-day we have enlarged our plants to heat several buildings, as in the University of Alberta, or in the central heating system in Winnipeg, that heats many business blocks and homes.

Exercises:

1. Make a study of how your school is heated.
2. Watch the smoke as it rises from a bonfire and give an explanation of its behaviour.
3. Hold an iron rod in your hand and place one end in a fire. How did the heat travel to your hand?
4. As you sit at a bonfire, why is your face hot while your back is cold?

PROBLEM VIII: What are some labour-saving devices developed through scientific research?

Newspaper article, October, 1938:

> "A mechanical cotton picker in 1937 gathered 121 bales of cotton, at an actual cost to the operators of eleven cents a hundred pounds, while field hands were paid in the same district an average of one dollar per hundred pounds."

This is indeed a machine age. Each invention has been followed so closely by its introduction into industry that labour-saving devices are now found in every sphere of human activity.

On the farm, the tractor has largely replaced the horse. The binder and threshing machine are being replaced by the combine or, as in the Drumheller area in Alberta, by the "barge", a device that takes care of binding and stooking without the need for binding-twine or man-power. Energy supplied by power lines, gasoline engines, or even windmills, pumps water for the farm, turns the separator, churns the butter, operates the washing-machine, chopping mill, or grind-

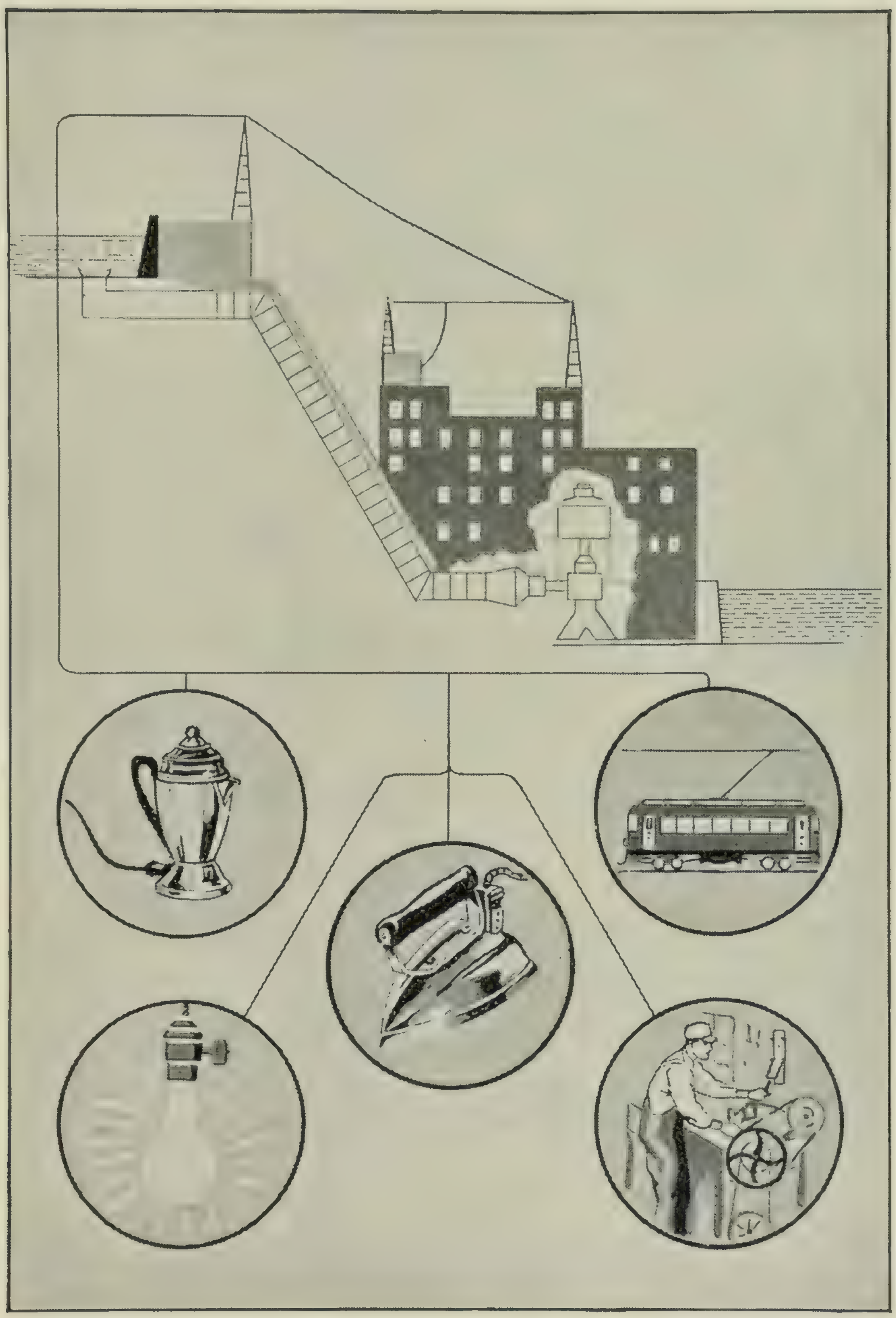


Fig. 20. Heat, light and kinetic energy derived from the potential energy of the water behind the dam.

stone, and makes possible the use of vacuum cleaners, polishers, and of various kitchen helps such as mixers, toasters, electric irons and stoves. Electric-, gas-, or kerosene-operated refrigerators are a source of joy to modern housewives.

The modern factory is filled with labour-saving machinery. It is said that a large flour-mill can be operated by as few as five men. Mass production has been made possible. In the garment factory, the electric knife will cut out twenty or more suits at one operation.

We see a gasoline operated "ditcher" doing the work of at least one hundred and fifty men in digging a ditch in which to lay water- or gas-pipes. Iron stokers feed coal into our boilers. Oil burners are automatically fed in our homes, ships or locomotives. Even the painter has discarded his brush for the spray gun when painting an automobile or the outside of a building.

Office workers now use such devices as typewriters, adding machines, comptometers, and bookkeeping machines. The mimeograph machine enables some hundreds of copies of a letter to be made from one stencil or master copy.

We might study many similar illustrations. See if you can answer some interesting questions.

Exercises:

1. Have you ever seen a windmill that generates electricity? If you have, describe it briefly.
2. Show how a dump truck is a labour-saving device.
3. Name some labour-saving devices that you have seen (a) in your home, (b) on a farm, (c) on your streets, (d) in some factory you have visited, (e) in your school.
4. Prepare a brief comparison of house-keeping fifty years ago and to-day.
5. Can you state any principles involved in some of the devices you have seen?

PROBLEM IX: What has science contributed to our means of entertainment?

When your mature scientist was a boy he did not have the means for enjoyment that we have to-day. The stereoscope amused him and enabled him to see why he had two eyes instead of only one. The magic lantern was "magic" indeed to him. The phonograph, the silent picture and then the talking picture were sources of wonder to him. Now, the radio brings the whole world into your home.

As a boy he did not move far from home. To-day, automobiles, fast trains, aeroplanes and fast steamships have brought us great pleasure in travel. Toronto is but nineteen hours from Calgary by aeroplane service. The motor caravan enables us to carry our "homes" along with us on our pleasure trips.

The music lover has benefited by the work of the scientist. The pipe organ that occupies so much space, is being replaced by the electric organ that uses, instead of pipes, the rotating disk.

Many other inventions might be mentioned, such as more efficient eye-glasses to relieve eye strain and permit greater enjoyment of good literature. Printing and the book-maker's art enrich our libraries. Many games of skill, such as golf and curling, are based on scientific laws.

Exercises:

1. Blow a tin whistle and see what happens as the air column is shortened.
2. Procure a stereoscope, if possible, and note that it is fitted with a magnifying glass for each eye. Why?
3. Stretch a violin or piano string tightly on a frame. Pluck the string. Place a bridge under the string half-way along its length. Pluck one end of the string. Note the change in pitch.
4. Visit a music dealer and ask to see an electric organ. Have the salesman explain the principle on which it works.
5. State some other ways in which the scientist has contributed to our means of entertainment.

TOPIC II—WATER

UNIT 2. MAJOR STUDY: Water is an essential factor in the environment of all living things.

A. MINOR STUDY: Water is abundant and occurs in various forms.

PROBLEM I: Where does water occur?

When the earth was very young, perhaps the water was floating in the air in the form of clouds and came down as rain, or it may have come from within the earth to form lakes and finally oceans. Scientists have made little progress in solving this riddle.

If the earth were perfectly level, water would cover it to a depth of 2 miles. Of course, water has seeped into the earth to form underground rivers. Imperfect drainage has left inland lakes, ponds, sloughs, and rivers, yet the real storehouses of the water on the earth are the oceans and seas that cover more than three-fifths of the globe.

PROBLEM II: In what forms does water occur?

Solids, liquids and gases.

We have no difficulty in believing in the reality of solids and liquids; they occupy space, have weight, and may be felt. Usually it is easy to tell the difference between the two classes. Unless force is applied to a solid, as in the stretching of rubber, it retains a definite shape. A liquid assumes the form of any vessel it may fill, and if it does not occupy the whole of the container, the upper surface, when at rest, is flat. Although the shape of a liquid is changeable, its bulk or volume, like that of a solid, does not change.

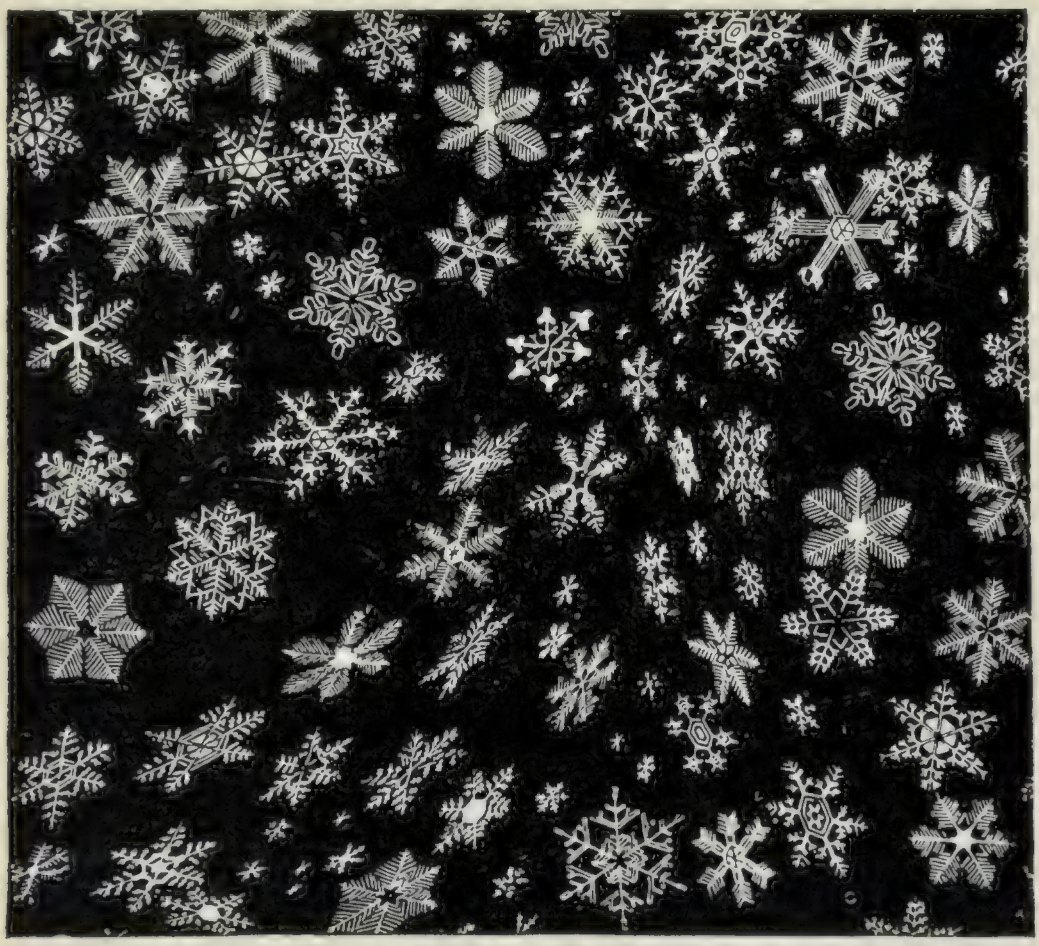
It is untrue to say that solids never flow. The enormous force exerted by a shell may cause the steel armour of a warship to "flow" at the point of impact. When this happens, the object penetrates the steel. When coins are being made, the solid metal, under great pressure, flows into the hollows of the steel dies.

We may exist for a few days without water, but, lacking air, we die in a few minutes. This necessity of life is a member of a third class of matter, the gases.

Gases are the "untouchables" of the material world. Ordinarily we are unaware of their presence. Only when they are in motion, like wind, which is moving air, or when, like the hydrogen sulphide which escapes from stale eggs, they possess odours, or when, like the deep violet vapour of iodine, they are coloured, do they seem real.

Snow and ice.

If we were asked to name substances with which we are familiar in both solid and liquid form, our list would be a very short one. Of all common substances water



(Courtesy of L. A. De Wolfe.)

Fig. 21. Snow crystals.

affords the best example of how matter may exist as solid, liquid or gas.

When water freezes, the liquid in which we sink or swim is changed into a solid that may wreck an ocean liner. In spring the miracle is reversed; the jaunty snowman loses his pipe, his hat, and then his identity, as he trickles over the lawn.

Snow crystals.

A snow flake is made up of a number of structures called crystals. More than a thousand of different forms have been photographed and many are of amazing beauty. On a piece of black cloth catch a few dry snow flakes and examine them with a hand lens. Have the different forms of snow crystals any features in common?

Copper sulphate crystals.

Some may be interested in examining other crystals. Powder some copper sulphate and stir it with hot water. Pour a little of the blue liquid on a watch-glass or saucer. Leave the dish where it will be undisturbed and examine it after twenty-four hours.

Pick out one of the more perfect crystals and suspend it by means of a hair in copper sulphate solution. By this means quite large crystals may be obtained.

Water in the gaseous state.

Out of doors, water may be freezing or snow may be melting, but on the kitchen stove a different change is taking place. Heat is changing the liquid to gas. Close to the spout of the kettle nothing can be seen; an inch away there is a whitish mist. For several good reasons we know that there must be something present in the apparently vacant space. That invisible something is steam. Frequently we call the mist 'steam' but this is incorrect. As soon as the hot vapour is cooled, it changes back into liquid. The mist consists of tiny particles of the liquid moving through the air. Usually, these small particles change into vapour again and are lost in the air of the room.

The condensation of steam (Steam to liquid water).

Set up the apparatus shown in Fig. 22. The flask contains water in which one or two little pieces of glass or broken flower pot are placed in order that the boiling may not become too violent. The test-tube is surrounded with snow or cold water. Continue to heat the flask gently after boiling begins.

What changes of state are taking place?

The evaporation of water (Liquid water to vapour).

If you have carried out the suggestion of making copper sulphate crystals, you have already observed the disappearance of water due to evaporation. This is familiar in the drying of clothes and the disappearance of water on the streets after rain.

Place two saucers containing a little water in a cupboard. Cover one and leave the other exposed to the air. In which is the conversion of water to water vapour more rapid?

Evaporation is most rapid when the water is boiling; the more vigorous the boiling, the quicker is the change from liquid to gas.

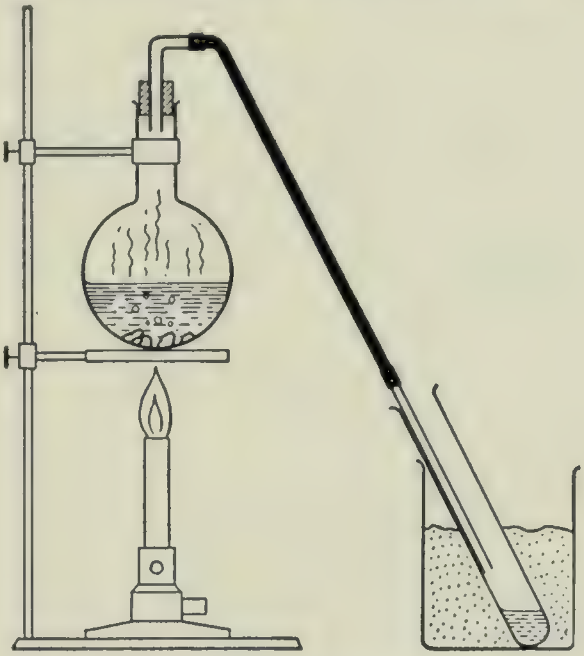


Fig. 22. What changes of state are taking place?

The formation of dew.

When moisture-laden air is cooled, the vapour may be condensed to water droplets. On warm summer evenings dew results from the formation of these droplets on vegetation or other objects near the earth's surface. (Much of the dew on vegetation is caused by the condensation of water vapour coming from leaves. Plan a simple experiment to show that vapour arising from the soil also may condense to dew when it meets the cool night air.)

PROBLEM III: What do we mean by sublimation?

The direct change from solid to gas and back again to solid is known as *sublimation.* If a block of ice is left outside in zero weather, over a period of time there will be a loss in weight because ice is said to sublime. When wet clothes are put on the line in very cold weather, after some time they lose their stiffness and become dry. Why? Will a wind assist in this drying?

A direct change from vapour to solid frequently occurs in our houses. In winter, the window panes may become so cold that the vapour which comes into contact with them is transformed, not into liquid, but into solid. Hoar frost is produced in the same way.

Dry ice is simply frozen carbon dioxide. It is dry because it sublimes and goes into a gaseous condition without becoming a liquid. Moth balls are made of a substance that sublimes, namely napthalene. While this substance produces an odorous vapour, it never produces a liquid to stain clothes.

Great stores of pure carbon dioxide gas under great pressure have been found at the Tampico oilfield in Mexico. In the Quebrada field it is estimated that the reservoir of gas is sufficient to give out 150 million cu. ft. a day and produce 9,000 tons of dry ice. This "ice" is carried in refrigerator cars to any place which may need it.

Exercises:

1. State some uses for dry ice.
2. Is there any danger to human life if dry ice is used in large amounts where ventilation is poor? Explain.
3. The freezing point of carbon dioxide is about 78 degrees Cent., while that of water is only 0 degrees Cent. What will happen when any exposed part of the human body comes into contact with dry ice?

PROBLEM IV: Of what importance is water as a solid?

A low winter temperature has much the same effect as a great dam. Instead of rain, snow falls and remains in this solid form until spring. Then it changes to liquid and is of value to crops. Besides its value as stored water, snow acts as a protective covering preventing damage to plants and reducing the depth to which the soil freezes. Also, it provides a surface over which lumbermen may have logs hauled to the river. You will recall the use of snow by Eskimos in the building of igloos.

On the other hand, there are some disadvantages. Heavy snowfalls cause interruption of traffic on roads, city streets and railways; the cost of snow removal is an important item in the budget of many cities.

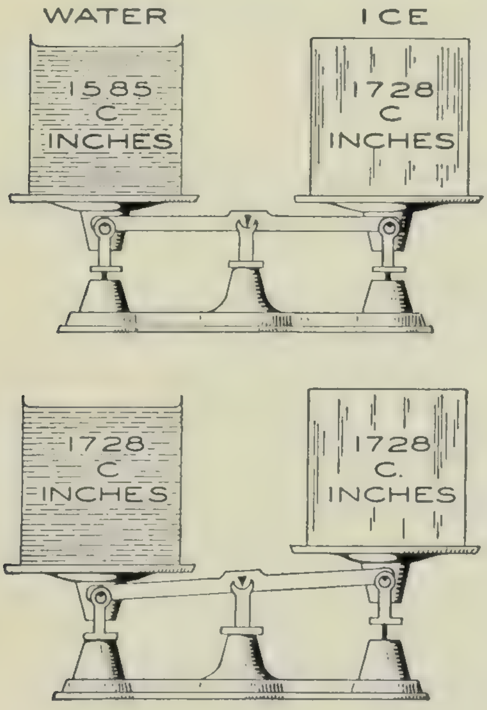
The alteration in bulk when water freezes.

Obtain a little bottle provided with a metal top. Fill it with water and screw the cover into position. Leave the bottle outside for a short time on a cold day. Describe what happens and give an explanation.

What damage may be caused by the freezing of water pipes? What precautions are taken by motorists in winter in connection with the water in the radiators in their cars?

Rocks and stones are broken down by the great force exerted when water in their crevices changes to ice of slightly greater bulk. Continued over a long period of years, this process contributes greatly to the making of soils. Land is ploughed in autumn to expose the soil to the expansive effect of freezing water. This helps to give the soil an open texture that makes it easy to cultivate in spring.

Since each cubic foot of ice is obtained from less than a cubic foot of water, it is clear that when equal volumes are compared the solid is lighter than the liquid. For this reason, ice floats on water, but, since the difference in weights of equal volume is small, most of the solid is submerged. It is interesting to know that about ninety per cent of even the hugest icebergs is invisible, but it is not so pleasant to think of the disasters of which they have been the cause.



WHEN A VOLUME OF 1585 C. INCHES OF WATER FREEZES THE RESULT IS 1728 C. INCHES OF ICE. THESE MUST HAVE THE SAME WEIGHT, HENCE

1728 C. INCHES OF ICE MUST BE LIGHTER THAN 1728 C. INCHES OF WATER

Fig. 23. When equal volumes of water and ice are taken, the latter is lighter than the former.

How is the height of water in a tumbler affected when a piece of ice in the water melts?

PROBLEM V: Of what importance is water as a gas?

Demonstration of the presence of water vapour in the air.

(i) Recall observations you have made which would show that water vapour is present in the atmosphere.

(ii) Place a glass containing water on a table and into the water drop pieces of ice. Observe closely the outside of the tumbler. Does the experiment provide any evidence that the air of the room contains water vapour?

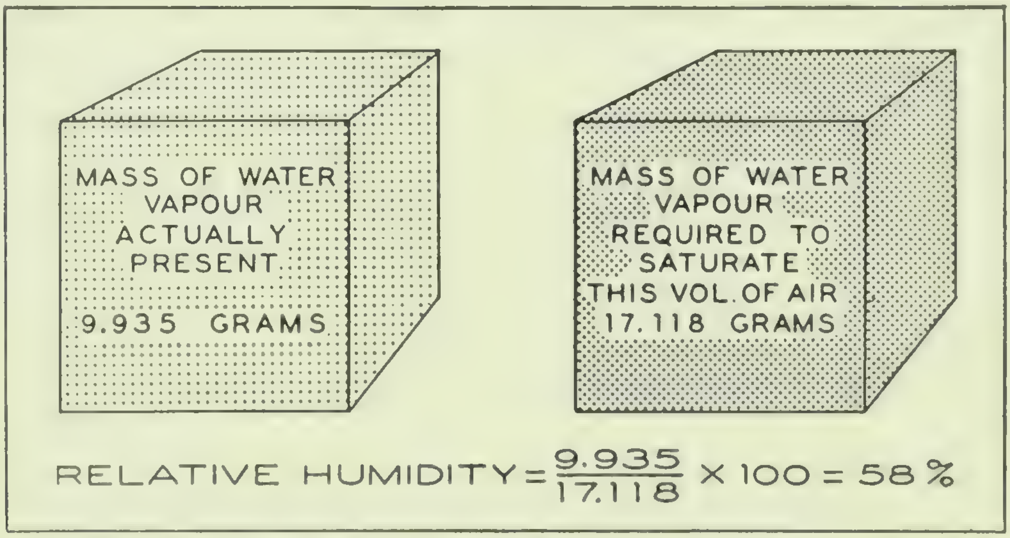

MASS OF WATER VAPOUR ACTUALLY PRESENT
9.935 GRAMS
MASS OF WATER VAPOUR REQUIRED TO SATURATE THIS VOL. OF AIR
17.118 GRAMS
RELATIVE HUMIDITY = 9.935/17.118 × 100 = 58%

Fig. 24.

(iii) Leave some anhydrous copper sulphate (p. 57) exposed to the air for a time. Describe the change that takes place. What is your conclusion?

(iv) Paint a piece of paper with a solution of cobalt chloride in water. Dry the paper and notice the change in colour. What is the effect of breathing on the dried paper? Using this property of the substance, how would you show that the amount of water vapour in the air varies? How may cobalt chloride be used as "invisible ink"?

Water in the form of vapour is continually entering the air. From oceans and rivers, from active volcanoes, from the soil, from drying clothes, from the exhaust pipes of automobiles and from a million other sources, great and small, the liquid vaporizes into the atmosphere. The proportion of water vapour in the air is quite changeable; an average amount would be in the neighbourhood of 1½ per cent by volume. This may appear small, yet from this vapour come the clouds, rain, hail and snow. It is estimated that sixteen million tons of rain or snow fall on the earth every second.

Comparison of the cooling effect of two liquids which differ in their rates of evaporation.

Place on your hand a drop of water and a drop of ether. Which is more quickly vaporized? Do you notice any difference in sensation at the spots where the drops were placed?

Does this little experiment prove that the more rapidly evaporation takes place, the greater is the cooling effect produced? Why not?

Let us consider the experiment as one which will illustrate rather than demonstrate the principle.

Suggest a reason why it is pleasant to fan the face on a sultry day. Why does a dog put out his tongue when he is hot?

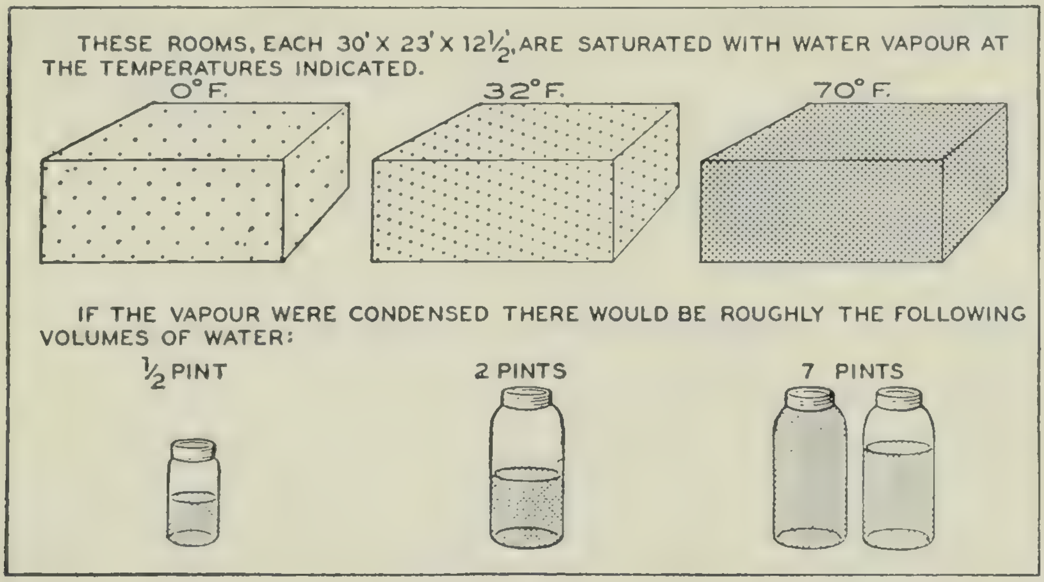

THESE ROOMS, EACH 30' X 23' X 12½', ARE SATURATED WITH WATER VAPOUR AT THE TEMPERATURES INDICATED.
0° F.
32° F.
70° F.
IF THE VAPOUR WERE CONDENSED THERE WOULD BE ROUGHLY THE FOLLOWING VOLUMES OF WATER:
½ PINT
2 PINTS
7 PINTS

Fig. 25. The amount of water vapour necessary to saturate a given space depends upon the temperature.

As everyone knows, a washing dries more quickly on a day when the air is dry than on one when the air is damp. Similarly, in dry air evaporation goes on rapidly from the skin and a cooling effect is produced. Hence, in a house where the air is very dry, a higher temperature must be maintained than in one with reasonably moist air. One result of this is the use of too much fuel. More serious is the effect on health; the hair, skin and mucous membranes of the nose, throat and lungs become dry so that liability to disease is increased.

Another effect is the shrinkage of woodwork of both house and furniture.

On the other hand, when the air contains nearly as much water vapour as it can hold, evaporation from the skin is checked. Because of this, we feel stifled on sultry summer days.

The degree of moisture in the air is of considerable importance in cotton-spinning. If there is too little water vapour present, the cotton breaks readily, if there is too much, the workers are caused discomfort. Lancashire has an advantage in the cotton industry because the air is quite moist.

Comparison of the volumes of water vapour and the liquid necessary to produce it.

Place a small amount of water in a flask and with a piece of gummed paper mark the level. Boil the water vigorously for ten minutes and observe the clouds of water droplets which are formed. It is true that these are not vapour, but they give us a rough idea of the volume of vapour produced. When the flask and its contents cool, note the new level. From the small volume of water which disappeared, a relatively large volume of vapour was obtained.

If the vapour or steam is allowed to escape freely, its volume is about 1,600 times that of the water from which it was derived. In other words, a cubic inch of water may give rise to nearly a cubic foot of steam. Should the steam from boiling water be not permitted to escape, it exerts pressure on the sides of the container and this may be great enough to cause an explosion—you have noticed how steam raises the lid of a kettle. The pressure exerted by compressed steam has been used to our great advantage in the steam engine, in which a piston is driven alternately back and forth by the expanding gas.

The theory of evaporation.

It is believed that solids, liquids and gases are composed of very small particles or molecules which are some distance apart from each other. The molecules of solids are closest together, those of liquids are farther apart, and those of gases still farther. (There are just as many molecules in a cubic inch of water as there are in the 1,600 cubic inches of steam into which it may be changed.) There are reasons for believing that the molecules are in motion, that they collide with each other and rebound. Moreover, they exert a pull or attraction on each other which increases as they approach.

Let us imagine what happens when a saucer of water is exposed to the air. (Of course, we know that there is evaporation and cooling.) The molecules of water are moving hither and thither at different rates. Some of the fastest-moving molecules at the surface escape into the air and, because of their rapid motion, go so far that they are pulled back into the water again by the attraction of their neighbours. More slowly-moving molecules leave the liquid but return again. The loss of the more rapidly-moving molecules results in a lower *average* velocity of those which remain. To this is attributed the lower temperature which results from evaporation.

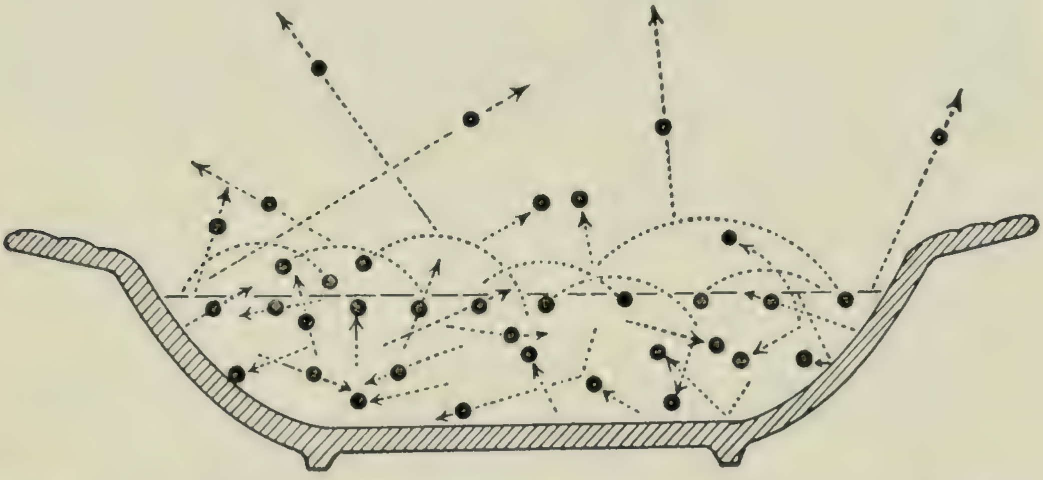


Fig. 26. The more rapidly moving particles near the surface escape into the air.

The hotter the water is, the faster the molecules move, and the more rapidly they escape into the air. Hot water evaporates more quickly than cold. If a current of air sweeps over the surface of the water, it removes escaped molecules which might have returned to the liquid. This agrees with observation; clothes dry more rapidly on a windy day than on a still one. An electric fan brings currents

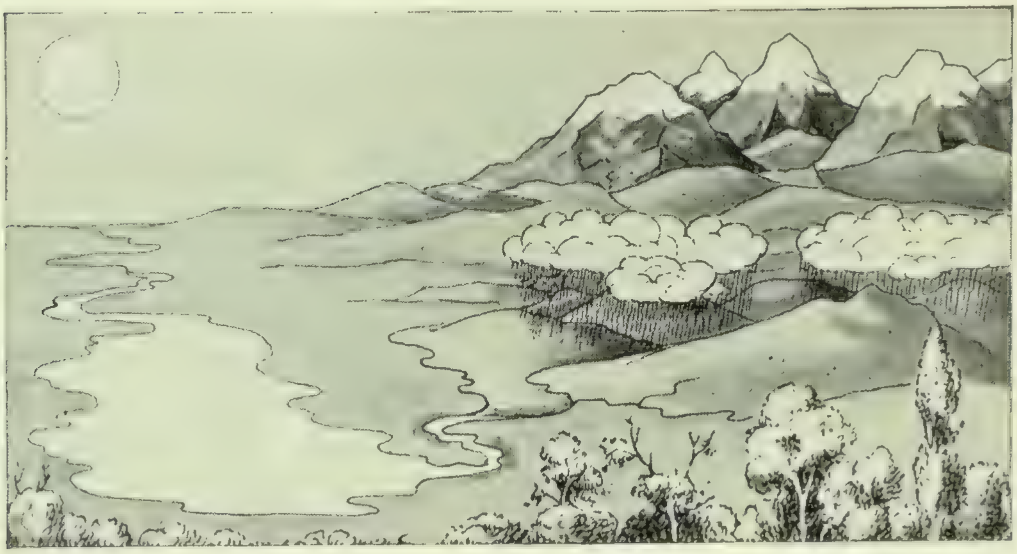


Fig. 27. What changes in the form of water are taking place in the scene represented above?

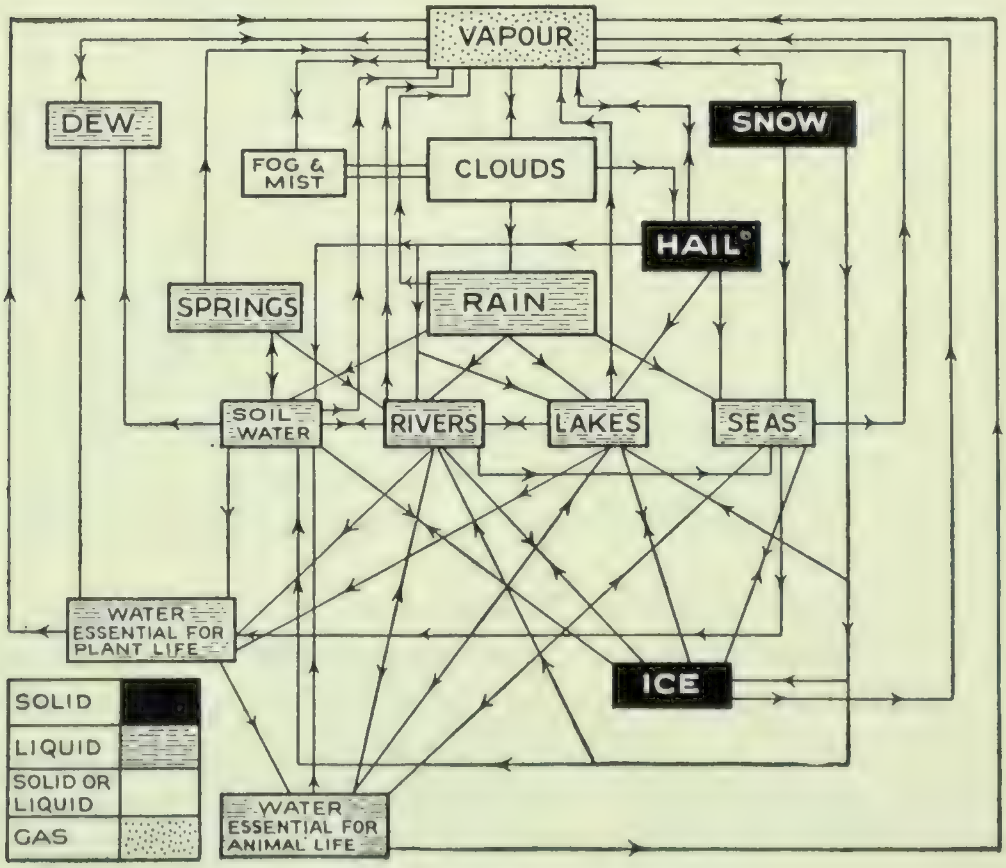


Fig. 28. The water cycle.

of air which hasten the evaporation of perspiration. The resulting cooling of our skin is a familiar experience.

1. Explain why wearing wet clothes makes one feel cold.
2. Why does one feel chilly in a draught?
3. Why are shallow containers used in the evaporation of maple sap?
4. Give a reason for the difference in a position of the radiators in a house and the pipes in a cold storage room.

PROBLEM VI: What is the water cycle?

We have learned that water may exist in three states. The atmosphere receives water vapour and gives it back in a variety of ways:

1. How the atmosphere receives water.
    a. Evaporation from all surfaces of bodies of water; from wet rocks and soil; from snow and ice (sublimation).
    b. Moisture is given off from the burning of fuels; by the breathing of animals; from trees and other plants.
2. How the atmosphere returns water.
    a. Condensation and the formation of rain, dew drops, and fog.
    b. If the temperature is very low, hoar frost, snow, and hail are formed.

Thus there is on the earth a never-ending cycle of water from solid or liquid to gas and back again from gas to liquid or solid.

Exercises:

1. Study the accompanying chart and follow the cycle through the various changes of state shown there.
2. What would happen in our environment if the cycle were altered (1) so that the atmosphere would receive no moisture? (2) so that the atmosphere would return no moisture to the earth?
3. What weather conditions cause water to change its form?
4. What evidence have you that water is the most abundant substance on the earth's surface?
5. Show how present conditions on the earth would be affected if water changed its form at temperatures other than 32° and 212° F.

6. Why is the water in our streams, lakes, and oceans never exhausted?

ENRICHMENT SECTION, NUMBER 2.

The locomotive.

Hero of Alexandria, a Greek who lived about 2000 years ago, is said to have invented the earliest steam engine. In this engine, the recoil of steam issuing from a jet was used to make an arm carrying the jet move about an axis.

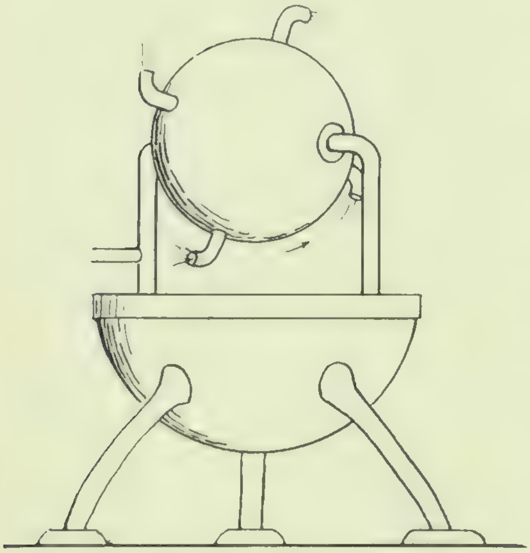


Fig. 29. Hero's engine.

The first practical engine of any kind was made by an English mechanic named Newcomen in 1705. It was used for pumping water out of a coal mine.

James Watt (1736-1819) invented the first steam engine practical enough to be used in industry. In his patent, Watt had a plan for driving carriages by steam.

The man who made the first really successful road-engine was Richard Trevithick (1771-1833). On Christmas Eve, 1801, his road locomotive carried its first load of passengers. In 1804, he made an engine that would run on rails at a rate of from five to fifteen miles an hour and draw a load of twenty tons. In 1810, he made the first steam plough.

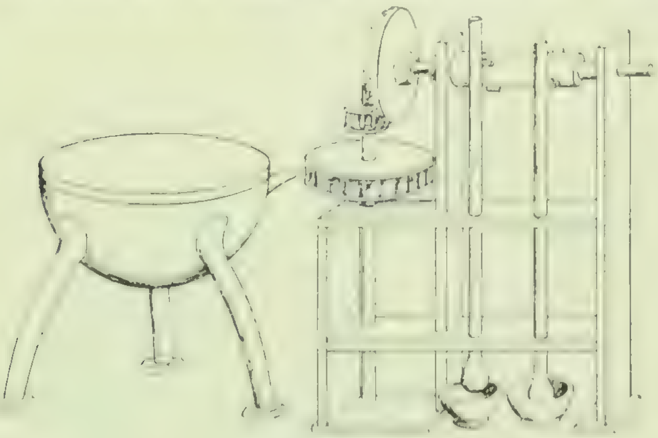


Fig. 30.

Before 1830, George Stephenson built his locomotive, the Rocket, which ran at thirty miles an hour. His son, Robert, made the

Planet which became the model of the engines of to-day.

Exercises:

1. When water is changed into steam at a pressure of one atmosphere, it expands about 1,700 times its original volume, and 1 cu. in. of water becomes about 1 cu. ft. of steam. What would you expect to happen if the boiling water and steam are confined in a closed vessel?
2. Secure a picture of the *Rocket* or *Planet* and place it beside a picture of a modern locomotive. Paste the pictures in your scrapbook.
3. Mount in your scrapbook as many pictures of locomotives built during the last two hundred and fifty years as you are able to find.

ENRICHMENT SECTION, NUMBER 3.

Steam marches on: The steamship.

After the success of Watt's engines in driving machinery had been proved, men began to think of using it on boats.

In 1707, Denis Papin built the first steamboat and set out to cross the English Channel. At Munden, the watermen smashed the boat to pieces because they feared it might destroy their living.

In 1813, Fulton completed a steamboat in France, but it broke into two pieces in a gale. On August 16, 1807, Fulton's *Clermont* completed its history-making trip from New York to Albany on the Hudson River, at about five miles an hour.

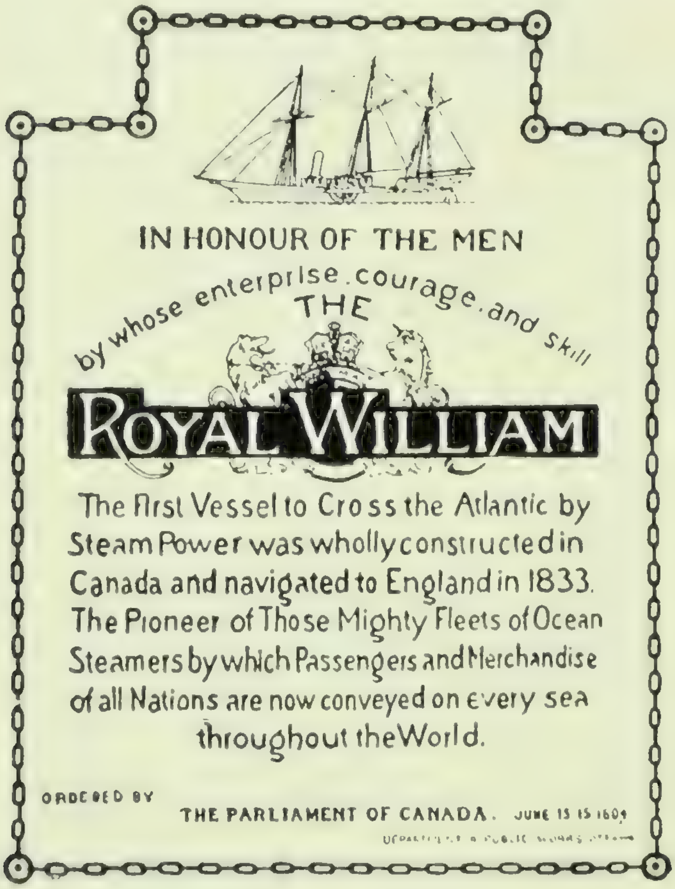
About this time, William Symington (1763-1831) and Henry Bell (1767-1830) were attempting the building of steamboats in Scotland. On January 12, 1812, Bell placed a steamboat, named the *Comet*, on the Clyde. It was of about twenty-five tons and was driven by a 3-horse-power engine at a rate of seven miles an hour. In 1814, London had its first steamboat plying the Thames.

In 1831, the *Royal William* was launched in the St. Lawrence near Quebec. Two years later she made a trans-Atlantic trip, the first vessel to cross the Atlantic by means of steam alone.

On May 28, 1837, the first screw-propelled steamboat towed a sailing vessel down the Thames.

The screw was of slow development, and the largest ship of the era, the *Great Eastern*, was a paddle steamer. Her greatest achievement was the laying of the first successful Atlantic cable in 1866. In 1837, the *Russia*, a screwship made the Atlantic crossing in slightly more than 8 days.

Various difficulties were overcome one by one. Steel replaced wood; oil replaced coal as fuel, and as a result, today we have modern liners like the *Queen Mary*.



IN HONOUR OF THE MEN
by whose enterprise, courage, and skill
THE
ROYAL WILLIAM
The First Vessel to Cross the Atlantic by Steam Power was wholly constructed in Canada and navigated to England in 1833. The Pioneer of Those Mighty Fleets of Ocean Steamers by which Passengers and Merchandise of all Nations are now conveyed on every sea throughout the World.

ORDERED BY
THE PARLIAMENT OF CANADA. JUNE 13 15 1609
DEPARTMENT OF PUBLIC WORKS OTTAWA

Fig. 31.

Exercises:

1. What great difficulty was met when steam vessels replaced sailing-ships? (Hint: the machinery took up much of the room previously available for cargo).
2. What navigational difficulty was met when iron was used in place of wood in shipbuilding? (Hint: Does iron affect a compass needle?)
3. Mount in your scrapbook some pictures of steamboats built in the last two hundred and fifty years.

B. MINOR STUDY: Water is useful everywhere in the world because of its ability to dissolve a large number of substances.

If we drop a spoonful of sugar into a glass of water and stir, some or all of the sugar disappears, and the water becomes sweetish. The sugar which disappeared is said to have dissolved and the sweet water is called a solution. Sea-water is a solution which contains common salt and, to a lesser degree, other constituents.

PROBLEM I: Do solids differ in the extent to which they are soluble in water?

Into three glasses pour the same amounts of water, equally warm or cold. To one, add two tablespoonfuls of sugar, to the second, two tablespoonfuls of common salt, and to the third, the same volume of sand or powdered blackboard chalk. Stir each of them in turn, with equal vigour, for half a minute.

Compare the quantities of the solids which remain in the glasses. Which substance was most soluble in the water? What was least?

Compare the solubilities of other solids in water. Do sugar and copper sulphate dissolve more readily in hot water or in cold? Can you notice any difference in the amounts of common salt which dissolve in the same quantities of hot and cold water?

NOTE: If the above experiment and those described in the section following are performed by each member of the class, it is advisable, of course, to use test-tubes and small amounts of water and solids.

PROBLEM II: Is there any limit to the amount of a soluble solid which can be dissolved in a given amount of water?

Pour a little water into a beaker or tumbler, add a small quantity of sugar, and stir until all is dissolved. Then put in a little more sugar and stir again. Repeat this until you can give a definite answer to the above question.

Repeat the experiment, using common salt, Epsom salts (magnesium sulphate), and other soluble substances. How does warming the water affect the amount of substance that dissolves?

You have observed (a) that substances vary greatly in the degree to which they are soluble in water, (b) that some substances are more soluble in hot water than in cold, and (c) that, unless the water is heated, no more than a certain quantity of soluble substance can be dissolved in a given amount of it.

When water can no longer dissolve any more of a substance, the solution is described as a *saturated* one. If, like most substances, the one in question is more soluble in hot water than in cold, it is, of course, possible to make more of it dissolve by warming the water.

PROBLEM III: Does ordinary tap or spring water contain dissolved solids?

Pour a little tap or spring water on a clean dry watch-glass. Cover the glass loosely and leave it in a cupboard. Near it leave another watch-glass containing distilled water, and similarly covered.

When the water evaporates, examine the watch-glasses. What conclusion do you come to?

Water can dissolve more substances than any other known liquid; in other words, it is the best of our solvents. We have referred to sea-water as a solution, but fresh water, whether from lake, river, or spring, also contains some dissolved solids. It has been estimated that in a year sufficient lime is carried in solution by the Thames to the sea to make enough oyster shells to cover one square mile a foot deep.

We are able to taste solids because they are dissolved, to a greater or less degree, in our saliva, which is largely water.

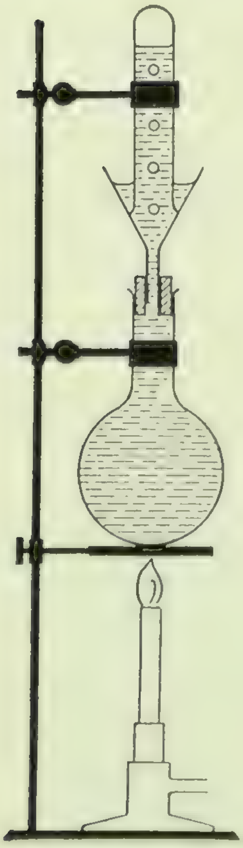


Fig. 32. Experiment to demonstrate the presence of dissolved air in water.

PROBLEM IV Can air be dissolved in water?

All of us have seen bubbles escaping when a bottle of ginger ale is opened and from this might infer that a gas has been dissolved in the liquid. Evidence that air dissolves in water may be gained from the following experiments.

1. Fill a tumbler with cold tap water and let it stand in a warm room for an hour or so. Notice the little bubbles that collect on the bottom and around the sides of the glass.
2. Place a dish of cold water on a hot stove. Notice the number and size of the bubbles that rise as the water gets hotter and hotter.
3. Fill the round-bottomed flask (Fig. 32) with water, and insert the cork into which a funnel has been fitted. Ensure that no air space is left under the cork and then pour a little more water in the funnel. Invert a test-tube filled

with water and support the flask by a piece of gauze wire resting on a ring. Heat the flask gently and notice whether any gas collects in the test-tube.

This air dissolved in water is necessary for all aquatic life. Fish cannot live in water that has been boiled and then cooled.

Nature has various ways of putting air into water. Air enters water as it passes over water falls or is stirred up by winds. Rain also carries much air into the waters of the earth's surface.

PROBLEM V: How can water be freed from any dissolved or undissolved solids it may contain?

Set up the apparatus shown in Fig. 22 and add a tablespoonful of common salt to the water in the flask. Boil as before. Taste some of the liquid which condenses in the test-tube. Has it a salty taste?

Empty the test-tube and put muddy water in the flask. Describe the liquid which collects in the test-tube after boiling has continued for some time.

The water in the test-tube is free from the impurities placed in the flask. It is described as "distilled" water and the process is known as distillation.

Distillation is a most efficient, but expensive, method of purifying

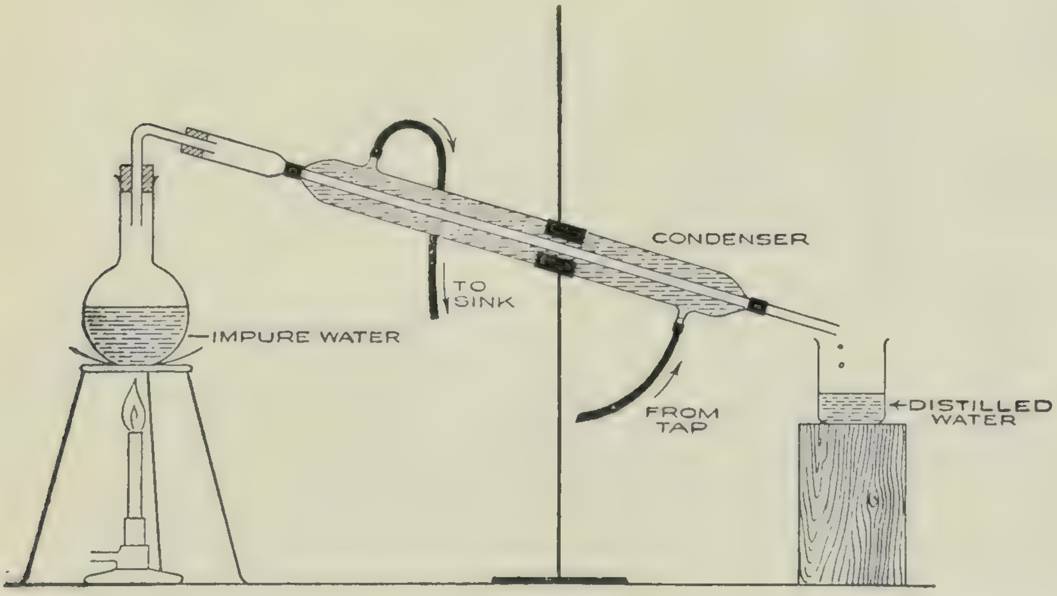


Fig. 33. The Liebig condenser. The vapour from the impure water is condensed by the jacket through which a slow stream of cold water flows. The distilled water, or distillate, is free from the impurities.

water. On many ships, it is used in obtaining drinking water from the sea.

(1) Perform a simple experiment to show the difference in the amount of dissolved solids in water from snow and tap water. Why would you expect more residue from the tap water?

(2) Why is sea-water salty while that in the Great Lakes is fresh? Account for the saltiness of the water in the Dead Sea and Great Salt Lake.

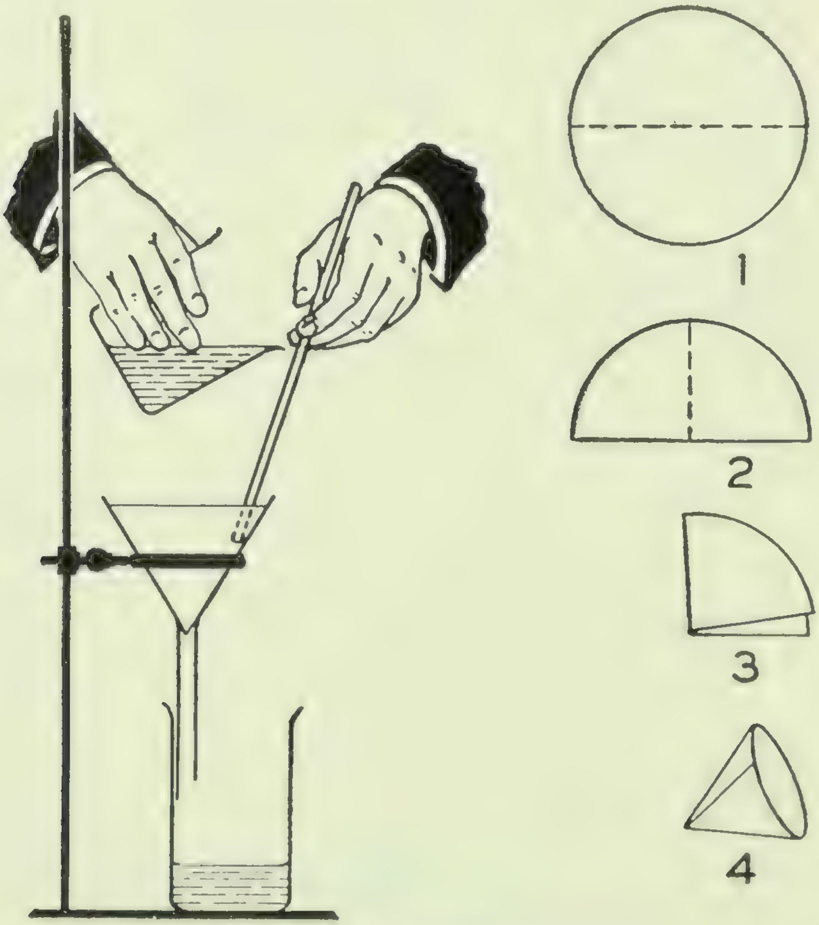


Fig. 34. The process of filtration.

(4) Can a dissolved substance be separated from a liquid by means of filter paper? Try this experiment. Place a crystal of potassium permanganate in water, stir and filter.

(5) If you suspected that sugar was adulterated with sand of the same colour, how could you find whether or not your suspicion was groundless?

PROBLEM VI: How does water act as a cleanser?

Water acts as a cleansing agent in different ways. If the dirt is loose and does not dissolve in water, it may be rinsed away. The unwanted particles are carried off like dust swept away by a wind.

Just as sugar dissolves in tea, so the dirt may dissolve in the water and be carried off. We are fortunate in that water is the best solvent; alcohol, the second best, is far behind.

Frequently it is necessary to dissolve some substances in water in order to remove dirt. Soap, of course, is most commonly used. There are a number of theories as to how soap acts. It is generally believed that dirt particles are fastened to the soiled object by means of grease. In some way the grease is attacked by the soap solution and the dirt is set free.

Soap and soft water.

Prepare a little soap solution and add it, drop by drop, to a test-tube half full of rain water, water obtained by melting snow, or distilled water. After covering its mouth with your thumb, shake the tube vigorously. Note the amount of soap solution necessary to form a lather.

Soap and hard water.

To a test-tube half full of hard water, add the quantity of the soap solution necessary in the previous experiment to form suds. Shake the test-tube vigorously. Can you obtain a lather? Continue to add soap solution, shaking the tube after each addition, until suds are produced. Compare the quantities of soap solution necessary in the two experiments. (If hard water is not available, add a small amount of Epsom salt or calcium chloride solution to soft water.)

Why is hard water unsatisfactory for cleansing purposes?

Notice the deposit which forms on the inside of kettles. When very hard water is used, how does the quantity of the deposit differ from that found in places where the water is softer?

Water is said to be ‘hard’ when it contains certain (dissolved) substances which combine with soap and produce insoluble material or ‘curd’. Only by adding great quantities of soap, enough to use up the dissolved substances in making curd, can you get a lather. This is expensive, so washing soda or ammonia, both cheaper than soap, are often used instead.

Lime is a common cause of hardness in water. When water containing it is boiled, the lime is changed, so that it becomes insoluble and hence, cannot affect the soap. We are familiar with the deposits of lime in kettles. Water which may be softened by boiling is said to have *temporary* hardness.

These materials which produce hardness come from the rocks or soil. Hence, rain water, caught before it reaches the ground, is always soft.

Exercises:

1. Are there any substances that cannot be dissolved in water?
2. What other common liquids are used as solvents?
3. What is meant by the term "tincture of iodine?"
4. Do you think that we will ever be able to discover a solvent that will dissolve any and every other substance? What kind of a vessel would hold such a substance?
5. Why are clothes rinsed before they are hung out to dry?
6. What gas is dissolved in soda water or pop? Why does pop "fizz" when the cork or cap is removed?
7. Will gold fish live in a jar of cold boiled water? Explain.
8. Why is rain water soft?

C. MINOR STUDY: All living things require water.

PROBLEM I: How is water useful to plants?

Before a seed will sprout, moisture must be present. After germination has taken place, water, in large or small quantities according to the type of plant, must be available or death will finally result. Mineral salts necessary to the growth of plants are brought to them dissolved in water. In the process of food manufacture in the leaves, the liquid plays a very important part.

We find a wide difference in the demand for water by plants. The cactus and the lichen, for example, can live in very dry places. A medium amount of water satisfies the elm and the oak trees, and the wheat plant. The willow and alder do best in swampy or moist places. Cattails, bulrushes and reeds have their roots in mud and raise their foliage above the surface of the water. A little further from the water's edge we find plants such as the water lily with foliage afloat. In still deeper water are the submerged plants like water milfoil and Canada waterweed. Aquatic plants are not confined to fresh water. Along the sea shore, fastened to rocks sometimes above and sometimes below water-level, are the slippery sea-weeds.

Water in plant tissues.

(i) Recall the change in radishes or other juicy vegetables which have been exposed for a time to the heat of the sun.

(ii) Gently heat a little piece of wood or a short length of geranium stem in a clean, dry test-tube. Does any substance collect on the colder parts of the tube? If it does, describe its appearance.

(iii) Hold a piece of blue vitriol (copper sulphate) in a flame for a few minutes. Notice the disappearance of the blue colour. The white substance formed is called anhydrous copper sulphate. (This really means "copper sulphate without water.")

Bring the anhydrous copper sulphate into contact with water. The reappearance of the blue colour may be used as evidence that water is present.

NOTE: You should understand that you have not proved that anhydrous copper sulphate may be used to detect the presence of water, and water only. To establish this, it would be necessary for you to try the effect of all known liquids on the white solid. You have been informed that this test may be employed and you have observed the colour change.

(iv) Touch slices of potato, carrot and apple with anhydrous copper sulphate. Do these vegetables contain water? Is there water in a geranium stem?

(v) Select a fresh pigweed, lamb's quarters, or geranium plant. Wash all earth from the plant. Dry with blotting paper. Carefully weigh the plant. Place the plant in a drying oven or over a stove until thoroughly dried out but not scorched. Re-weigh the plant. Any loss in weight is caused by the loss of water that the plant contained.

PROBLEM II: How is water useful to animals?

It is unnecessary to emphasize the fact that water is as necessary for animals as for man.

Water, whether salty, brackish, or fresh is the home of countless billions of animals. For some, like that moving fortress the crayfish, the herring, and the fish-like whale, it is their only home. Others, like the frog, are purely aquatic for merely a portion of their lives. Then there are those which take readily to water but do not make it their only home. Among these are the turtle, the frog, the polar bear and those valuable fur-bearers, the beaver, muskrat, otter, mink and seal. Also, we call to mind the water-birds such as gulls and ducks, and others, less aquatic but interested in the water or its vicinity, like that keen observer on an overhanging branch, the kingfisher.

(Courtesy Nat. Museum of Canada.)

Fig. 35. A lake trout serves as a "Blarney Stone" in the north.

Aquatic animals supply many of our real and fancied needs. From the seas, lakes, and rivers we reap a great yearly harvest. Reference was made above to the importance to the fur industry of certain mammals that frequent the water. Then there are such items as codliver oil, sperm oil, spermaceti — a whale product used in preparing "cold cream", ambergris, pearls, caviar, shark leather, and the fertilizer made from fish refuse.

PROBLEM III: What other uses does man make of water?

When we describe something as "bone dry" we do not think that about one third of the weight of our bones is due to water.

It is not alone in beverages that we take water into the body; much of the solid food we eat is made up of it.

Water in food of plant origin.

Weigh a sliced radish, a sliced apple or other vegetable or fruit. Leave the vegetable or fruit on a dish beside or on a warm stove or radiator. From time to time, examine the food and weigh it. When the weight becomes almost unchanged, express the loss of water as a percentage.

NOTE: The percentage obtained will depend on the temperature at which the food is dried.

Water in food of animal origin.

(i) Gently heat a piece of meat in a clean, dry test-tube. Does any substance collect on the colder parts of the tube? If it does, describe its appearance.

(ii) Touch a piece of raw meat with anhydrous copper sulphate. Is there water in the meat?

(iii) Weigh a piece of raw meat. Thoroughly dry the meat in a warming oven or over a stove. Reweigh the meat. The loss in weight is due to the water removed from the meat.

NOTE: About 70% of the human body consists of water. An average adult contains about ten pints of blood. This blood is 85% water and 15% solids.

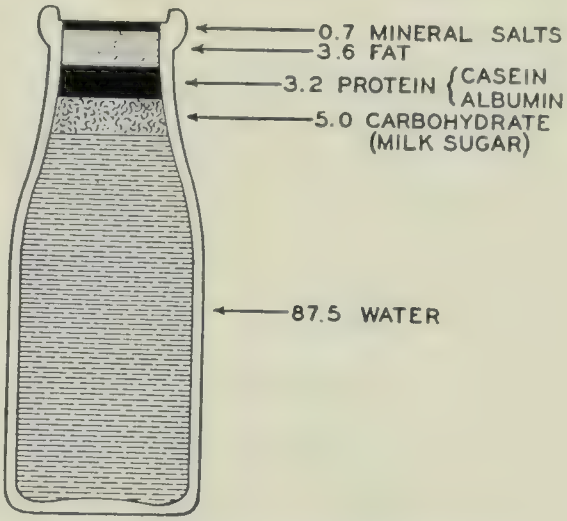


Fig. 36. The average composition of cow's milk.

Water plays a very important part in cooking.

Mix a little starch with cold water. Note the appearance of the liquid. Boil the mixture for some time. What change occurs?

Cooking breaks down cell walls. Also, it causes the fibres of meat to separate readily. The roughage in vegetables is softened by cooking. In the uncooked state it is often irritating to the intestines.

Extinguishing fires.

Three things are necessary for a fire: something that will burn, air and a kindling temperature. We put out a fire by removing any of these conditions. The air may be shut off by covering the burning substance with water, or water may be used to lower the 'kindling' temperature and keep it below the temperature of ignition for that particular substance.

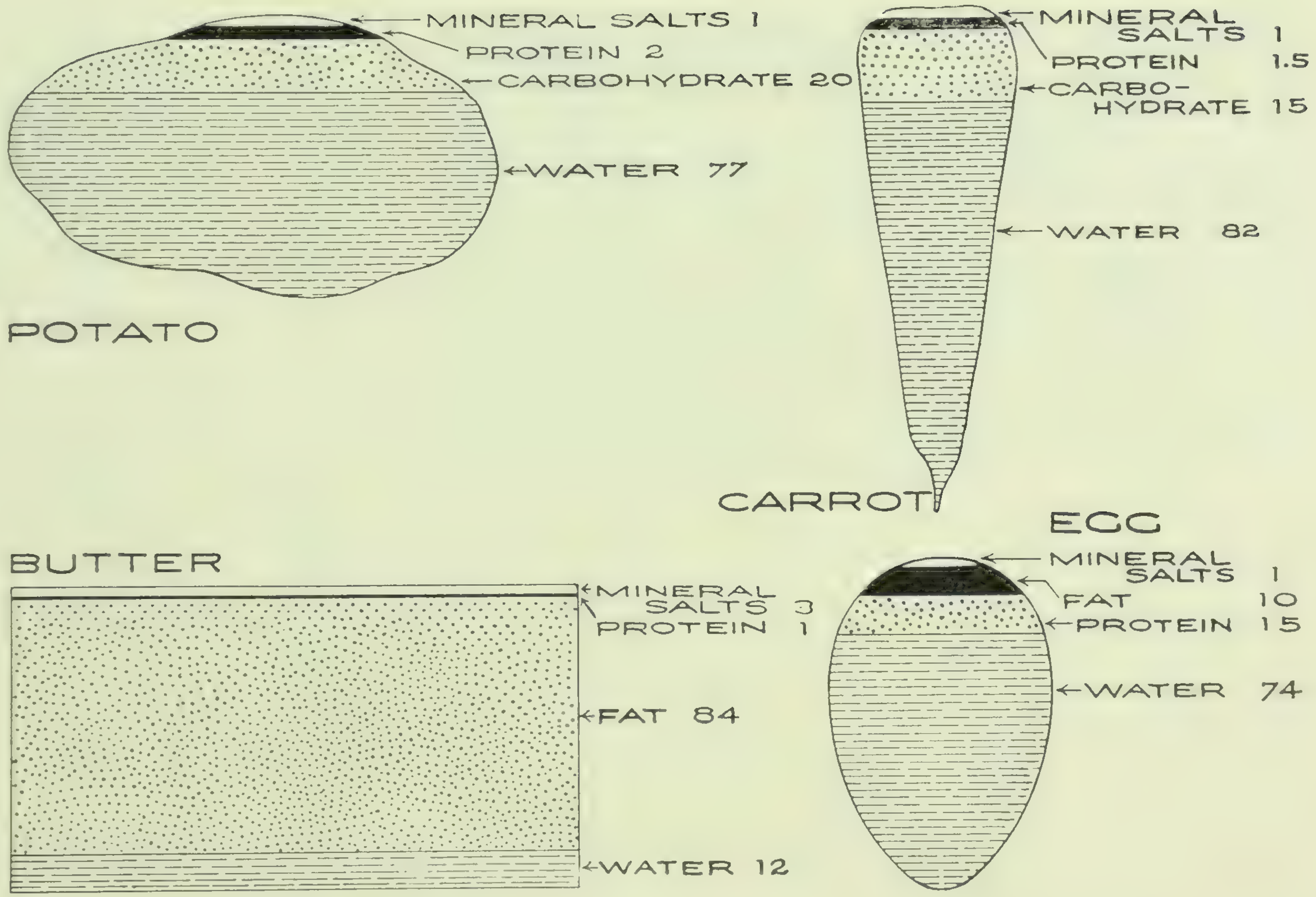


Fig. 37. The percentage composition by weight of four foods.

NOTE: Water should not be used to put out fires caused by gasoline or oil. Burning oil floats on water and is spread by it. Foam extinguishers are used in these fires. Sand or dust may be used also.

Water and recreation.

Man enjoys himself wherever water is found. He builds his summer resorts on the shores of rivers, lakes or seas and enjoys swimming, boating and fishing. The first snowfall at Mt. Norquay near Banff, brings many skiers there to enjoy the thrills of the slopes, or perhaps, to don snowshoes for an exhilarating tramp. As ice, water makes skating and curling possible. Even in the vaporous state, water offers enjoyment to those who like a steam bath after a plunge in the swimming pool.

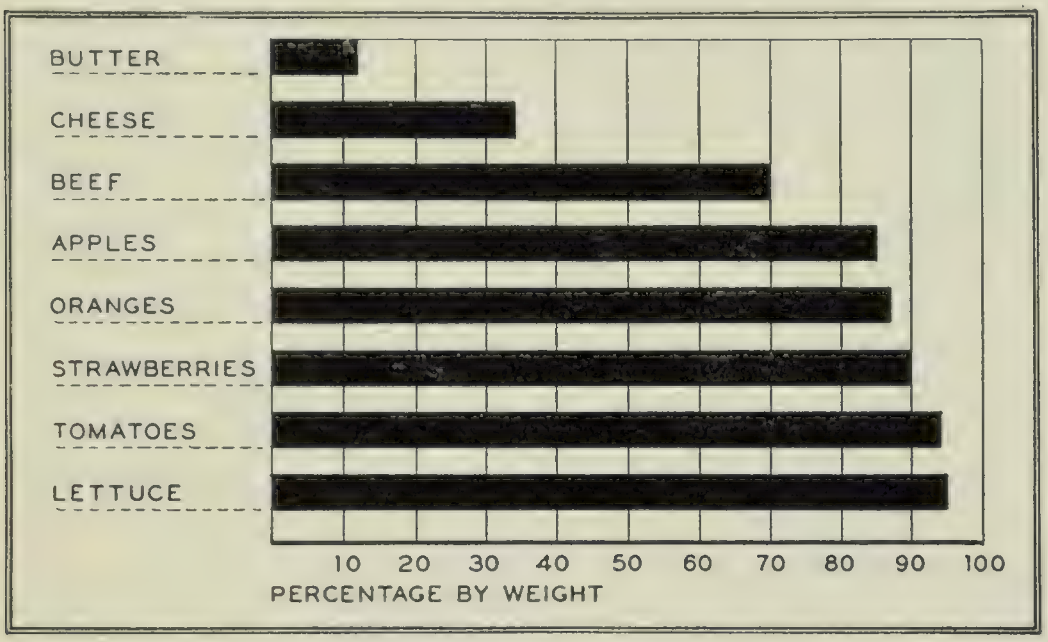


Fig. 38. The percentage of water in certain foods.

The removal of wastes by water.

The wastes of a household are of two kinds. Solids are called garbage; liquids are termed sewage.

For sewage disposal in rural homes the septic tank system is recommended. The septic tank is usually made of concrete, and has two compartments. Waste material is brought by water through a sewage pipe to the first chamber.

Solid matter falls to the bottom and is retained. When the liquid waste attains a certain depth, any excess flows into the second chamber. From this receptacle the fluid passes into a number of tiles which permit its seepage into the soil. Drinking water supplies must be protected against this seepage.

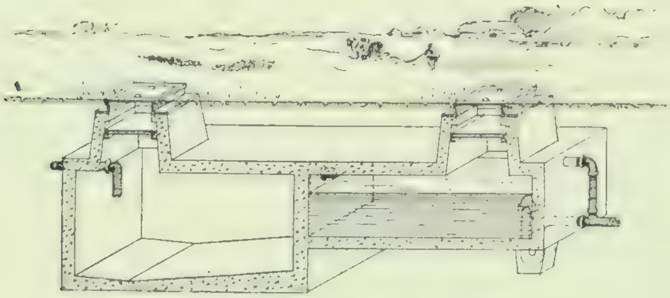


Fig. 39. Septic tank.

In the first or settling chamber, armies of bacteria present in wastes attack the solids reducing them to liquids and gases. These tiny organisms are killed or checked in their beneficial work by disinfectants, grease and large quantities of soapy water.

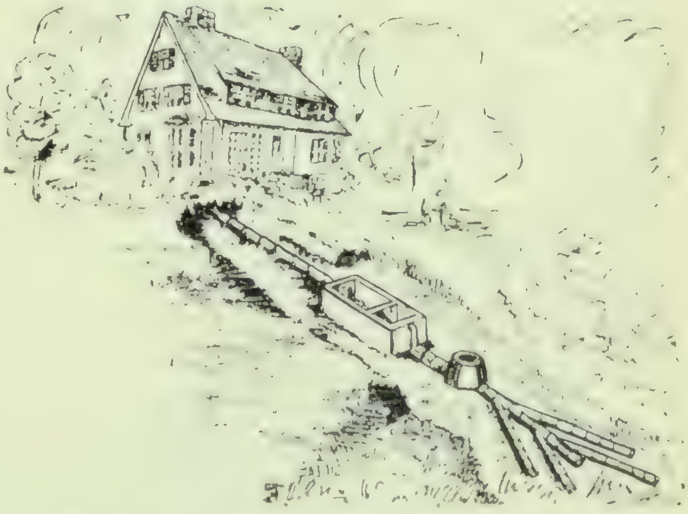


Fig. 40. The fluid from a septic tank passes into tiles.

Inland cities are under the necessity of treating their sewage. A sewage system disposes of the fouled waters from the community. The waste is collected in large septic tanks where it undergoes change through the agency of bacteria. The liquids emerging from the tanks pass slowly over beds of coke, sand and gravel where additional bacterial action takes place. This purified water is then disposed of through ground seepage or is emptied into nearby lakes or streams.

Cities near large lakes or the sea, dispose of their raw sewage by means of great pipes that carry it a considerable distance beyond the lower-water line, where it is purified by air and sunlight.

Exercises:

1. Study a drawing of a septic tank. Notice the siphon that connects the first chamber with the second. How does it work?
2. Make a drawing of the tile used to distribute the sewage over the largest possible area. How are the openings protected?
3. Where the soil is close and compact, these pipes are led into a cistern from which the sewage can be pumped. Include such a cistern in your drawing.

Water in industry.

Many and varied are the ways in which water enters into industries. Hydraulic mining has replaced the old-fashioned "Grizzly" of the pioneer prospector. In the hydraulic method, strong jets of water are used to tear up the gravel and wash it through the sluice where the gold, because of its weight, sinks to the bottom and is caught and held by cross bars.

Steam- or water-turbines have largely replaced the water-wheels of fifty years ago.

People used to be afraid to be caught in the rain lest their clothes should shrink. To-day the fabrics are sponged with high pressure steam in order to prevent finished garments from shrinking.

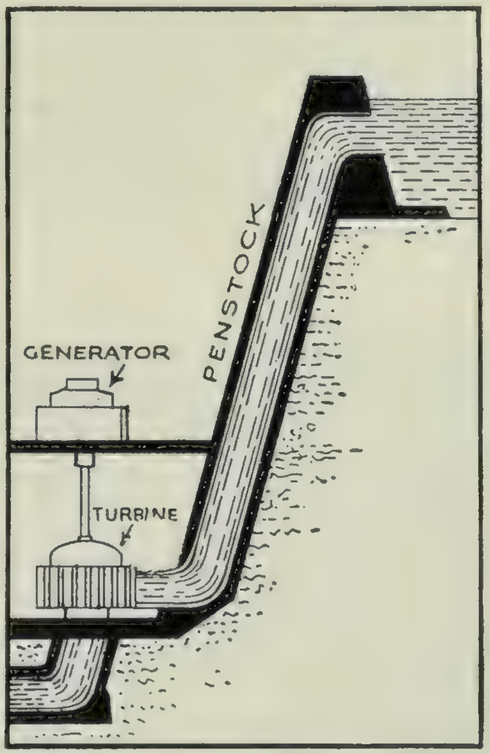
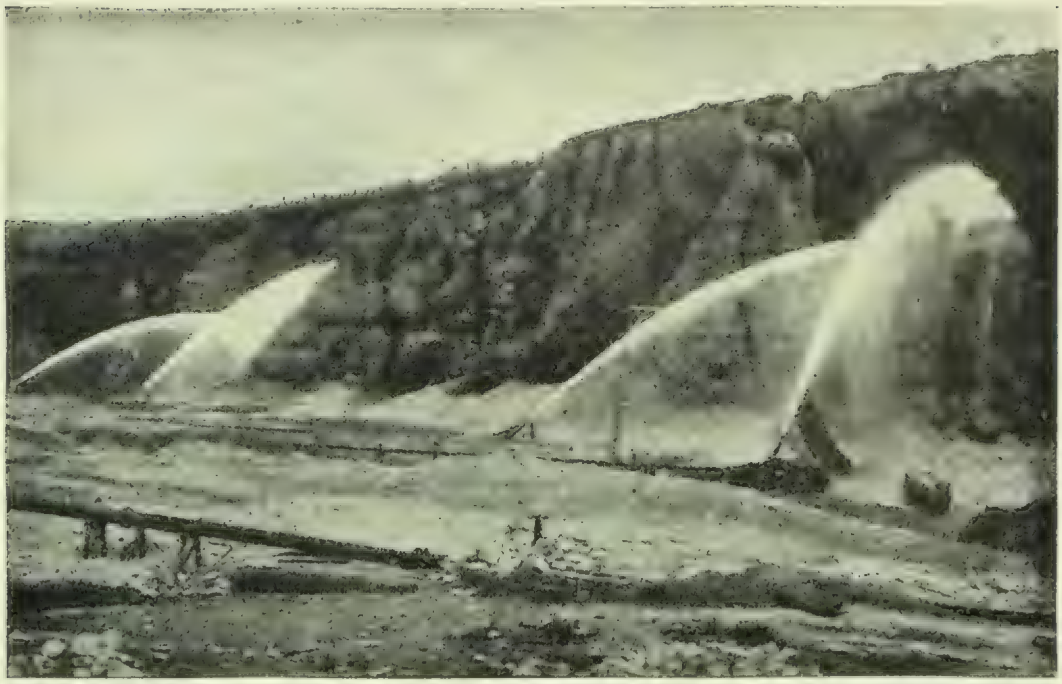


Fig. 41. Electric energy is obtained from the energy of falling water.

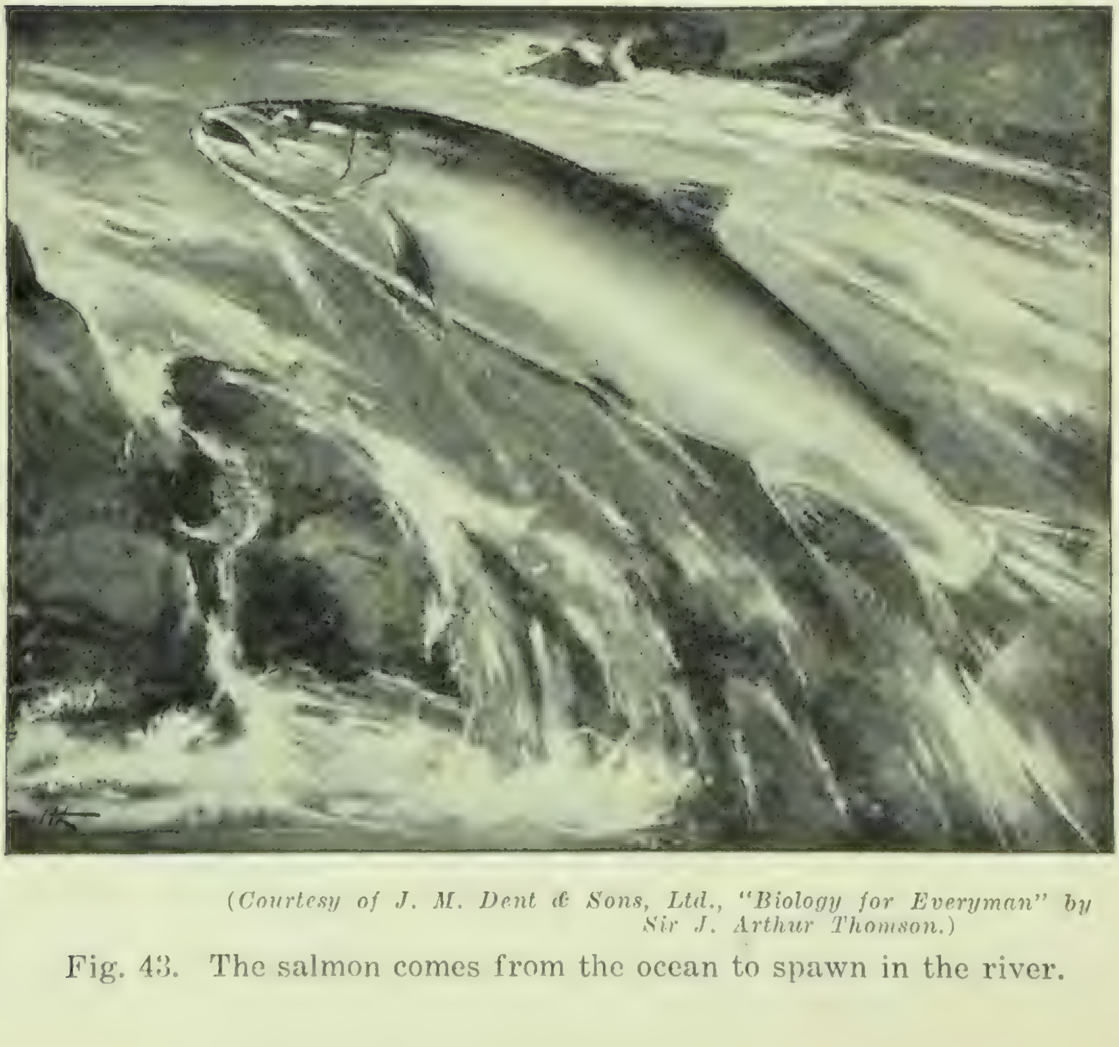
The great fishing industries of our inland lakes and sea coasts are made possible because water is the home of fish. Even much of the fur trade of the northern sections of Canada is dependent on water, either as a home of such animals as the seal, beaver and muskrat, or as a highway over which furs, before the advent of the aeroplane, reached a market from otherwise inaccessible locations.

The logger uses water as a highway when he floats his logs to the saw mill.



(Courtesy Dept. of Mines and Resources.)

Fig. 42. Water is used in mining.



(Courtesy of J. M. Dent & Sons, Ltd., "Biology for Everyman" by Sir J. Arthur Thomson.)

Fig. 43. The salmon comes from the ocean to spawn in the river.

Water vapour and forest fires.

You may remember an experiment in which pieces of ice were placed in a glass containing water. After a time, moisture was seen on the outer surface.

This experiment showed that there is water in the air. We use the term "humidity" when we speak of such water vapour in the air. When the humidity over forest land drops below forty-five per cent, twigs, leaves, needles, and "duff" dry out and become tinder. A chance spark of any kind may start a disastrous fire. When the psychrometer registers as low as thirty per cent, logging is stopped.

The irrigation of dry lands.

The southern sections of the prairie provinces must look to irrigation in the near future. Already much land in southern Alberta is irrigated. Fruits of many kinds are now grown under irrigation at Brooks, while the sugar industry of Raymond and Picture Butte is dependent on irrigated land.

Exercises:

1. What are the effects of dry air on health, furniture, and woodwork?
2. What do we mean when we speak of "air conditioning" our homes?
3. "When the humidity is high, cooking processes are slower." Is this statement justified?

D. MINOR STUDY: A community should protect its drinking water supply by sanitary control of the sources or by methods of purification of the water or by both.

PROBLEM I: How does a modern city ensure the purity of its water supply?

How to obtain good drinking water has long been, and still is, a very important matter. In arid and semi-arid regions the positions of wells have determined caravan routes and the location of towns; some idea of the value placed upon water by the Jews may be gained from the frequent allusions to springs in the Bible. Even when water is plentiful, the problem of how to secure a safe supply is sometimes a difficult one.

It is not always a simple matter to dispose of sewage without contaminating the drinking water.

We wish our drinking water to be cool, clear, sparkling, and free from unpleasant taste and odour. However, this is not enough. It is essential that poisonous substances and living disease germs be absent.

No matter how clear and sparkling water may be, no inference can be drawn concerning its freedom from disease germs. Whenever doubtful one should apply to the Provincial Department of Health, Edmonton, or the Central Experimental Farm, Ottawa, for information concerning the collecting and shipping of samples. These are analyzed without charge.

Disease germs.

Plants so small that they are invisible unless highly magnified are the cause of certain diseases such as diphtheria, lockjaw, tuberculosis, cholera, dysentry and typhoid fever. These little plants are known as bacteria, (singular, bacterium). Other diseases, for example, sleeping sickness, malaria, hydrophobia, and smallpox are produced by microscopic animals.

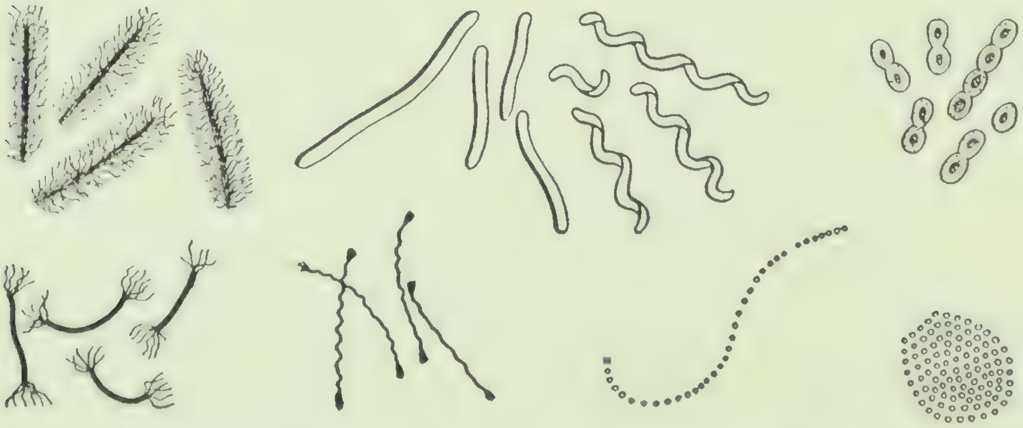


Fig. 44. Forms of bacteria. (Very highly magnified.)

In everyday speech these minute plants and animals are called germs or microbes.

Some bacteria are so small that, relatively speaking, one of them would have more room in a cubic inch of water than a man in Lake Superior. This illustration ignores the fact that the man's activities would be confined to a small depth, while the bacterium could roam at will in its enclosure.

Disease-causing bacteria may be found in the excreta of infected persons and animals. From this source the germs find their way into soil water and possibly, thence to wells and streams. Again and again, epidemics of typhoid fever have been caused by contaminated water. In one recorded case, the discharges of a patient suffering from typhoid fever were thrown upon the snow adjacent to his house. When the snow melted, the germs were borne to the water supply of a town with 8,000 inhabitants. Of these, 1,104 became ill with the disease and 114 died. Other diseases which may be spread by polluted water are diarrhoea, tuberculosis and dysentery. Also, there may be carried those parasitic pests, the tapeworm, roundworm and hookworm.

The provisison of water for towns in early times.

Three hundred years before Christ, the Romans constructed a channel for the conveyance of water to their city. In Carthage, rain-water for public use was stored in great cisterns. Generally speaking, however, the inhabitants of towns and cities in early days went for water to the most convenient well, stream, or lake. Those who could afford it purchased water, obtained from the same sources, at the door, just as blocks of ice are bought today. Clothes to be washed were brought to the stream or lake. When one considers the very unsanitary state of the soil which must prevail where many people dwell without modern means of sewage disposal, no surprise is felt at the prevalence of serious epidemics. Even to-day similar conditions are found in certain countries.

It was not until the thirteenth century that the first water-main was laid down in London. Before this time, however, it is probable that certain of the larger English monasteries had installed private waterworks. The absence of a supply of water under pressure was in great part responsible for terrible fires such as those which swept London in 1132, 1135 and 1161. To tear down the thatched wooden buildings by means of hooks, was the only way of checking the spreading flames. Toward the end of Queen Elizabeth's reign, there were erected elevated tanks filled with water by means of pumps. These co-operative efforts to provide drinking water were forerunners of what to-day is known as the public ownership of utilities.

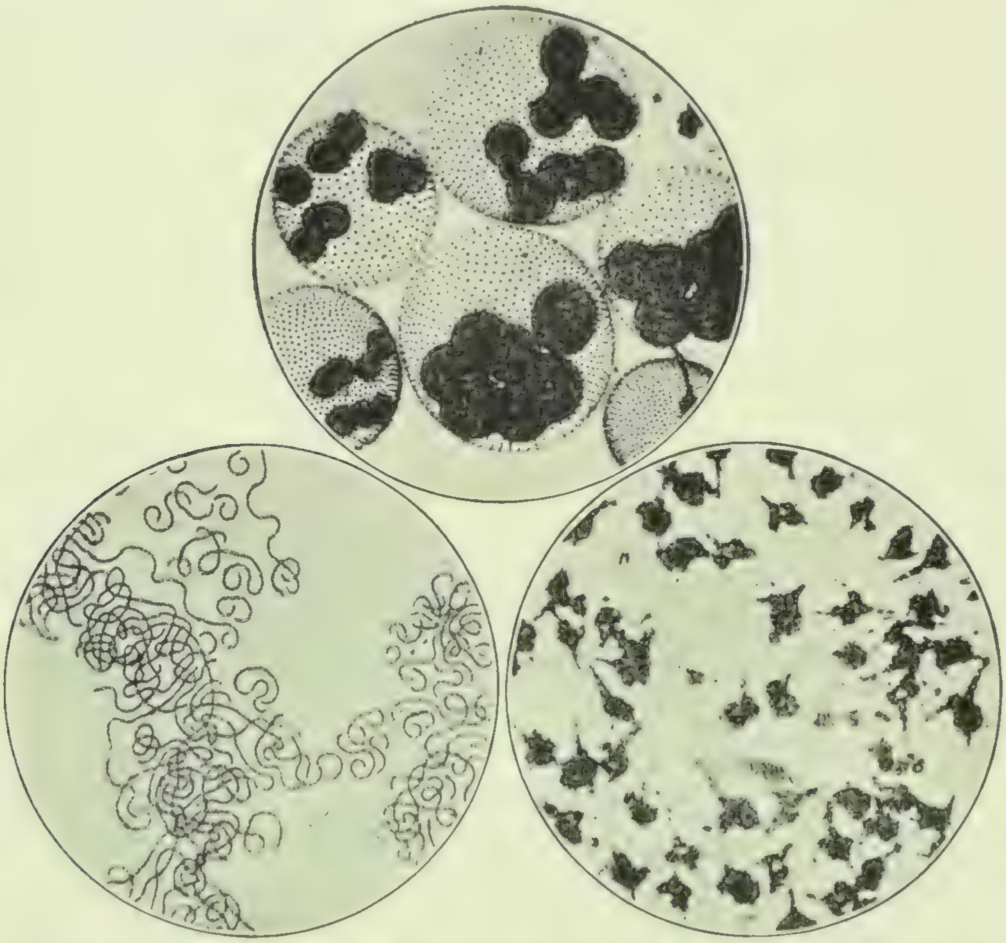


Fig. 45. Low forms of plant life found in unfiltered water. (Magnified.)

Top figure. Each of the six large circular structures is an alga called Volvox, and is really a colony of thousands of green cells. The prominent circular spots inside each Volvox plant are 'daughter' colonies.

Left figure. Anabaena: an alga which occurs in the plankton of lakes and ponds.

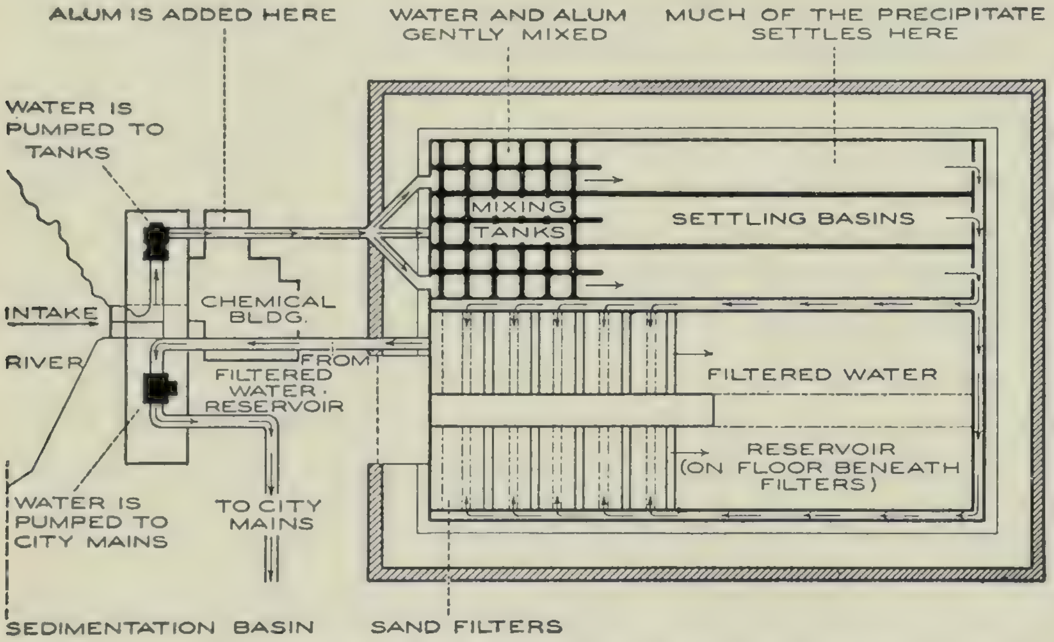
Right figure. Ceratium: an alga abundant in the plankton of lakes and ponds.

Sources from which modern cities obtain water.

The vast majority of cities and towns of this continent depend upon lakes and streams for their water. Cities such as

Toronto and Hamilton, which are situated on the Great Lakes, draw on them for their supply. Ottawa obtains its water from the Ottawa River. Edmonton takes its supply from the Saskatchewan River. Many cities have dammed rivers and thus have created artificial lakes. Calgary dammed the Elbow River creating the Glenmore Reservoir. The City of New York established reservoirs in the Catskill Mountains from which, by an aqueduct one hundred and thirty miles long, the water is brought to the city. To guard against pollution, a dozen villages in the drainage area were removed.

In regions of scanty rainfall, as in parts of Australia, the artesian well (See Fig. 47) is a very important source of supply. Gibraltar is on the edge of an enormous limestone rock a mile and a half long and 1,200 feet high. On the east side of the rock is a huge pile of sand about half a mile long and 700 feet high. Engineers have covered twenty-four acres of the top of this pile with corrugated sheeting fastened to a wooden framework. The rain falling on the corrugated sheeting is collected and led away to nine enormous reservoirs which have been hewn out of the solid rock. Every house in


ALUM IS ADDED HERE
WATER AND ALUM GENTLY MIXED
MUCH OF THE PRECIPITATE SETTLES HERE
WATER IS PUMPED TO TANKS
MIXING TANKS
SETTLING BASINS
INTAKE
CHEMICAL BLDG.
RIVER
FROM FILTERED WATER RESERVOIR
FILTERED WATER
RESERVOIR (ON FLOOR BENEATH FILTERS)
WATER IS PUMPED TO CITY MAINS
TO CITY MAINS
SEDIMENTATION BASIN
SAND FILTERS

(*Courtesy of W. E. MacDonald, Waterworks Engineer, Ottawa.*)

Fig. 46. Plan of a City Purification Plant.

Gibraltar has its own catchment area on the roof and a tank in the basement.

Purification of water.

If sewage be discharged into a lake from which drinking water is procured, great care must be taken in the process of purification. A similar situation exists when the sewage of a city enters a river above the point at which another city or town draws its water.

Although purification systems vary according to local conditions, there are certain common features.

If the water is muddy, it may be made to flow very slowly through a sedimentation basin in which the larger particles of undissolved substances sink to the bottom. Then it is passed downward through a filter consisting of sand; this completes the removal of undissolved matter. To hasten this removal, the water is often treated with aluminium sulphate, or filter alum, before it is filtered. This produces a jelly-like precipitate which entangles in itself, not only the fine particles suspended in the water, but also bacteria, and drags them down as it settles to the bottom. The alum also removes colouring matter. Precipitate on the surface of the sand and between the particles makes for greater efficiency of the process of filtration. It forms a kind of mesh structure which permits water to pass but entraps bacteria and suspended matter.

If germs are present, they are killed by chlorine gas added in small amounts after the water is filtered.

Chlorination of public drinking water has greatly reduced the number of cases of typhoid fever. There is reason to believe that most of those reported from cities providing filtered and chlorinated water may be attributed to the carelessness of people on vacation. In all cases of doubt one should boil water before drinking it.

Filtration of water.

Across one end of a lamp chimney fasten a piece of muslin. Support the chimney in an upright position so that the closed end is downward, and four or five inches from the table. Into it pour fine sand until the level is about two inches from the top. Stir some fine clay into water in order to produce muddiness. Pour this water into the chimney and collect the liquid which issues from the lower end. Compare the appearance of the water before and after its passage through the sand. What change has been effected? This experiment shows the action of soil in removing suspended solids from water.

The effect of aluminium sulphate.

Place equal quantities of powdered clay in two clear glass bottles each of which contains 100 cubic centimetres of water. After shaking the bottle vigorously add to one of them about 5 cubic centimetres of limewater and twice that volume of a saturated solution of filter alum (aluminium sulphate).

Allow the bottles to remain undisturbed for a time and describe what happens.

[NOTE: (1) If the clay is dry, it is advisable to soak it for a day or two before the experiment. (2) Limewater is prepared by stirring slaked lime with water and then filtering the milky liquid.]

The effect of aeration.

The oxygen of the air when dissolved in water tends to oxidize organic matter and to destroy bacterial life. When water is agitated so that fresh portions are brought to the surface, the oxygen of the air purifiès it. In many places drinking water is sprayed upward through many small openings and is thus purified.

Visit to a water purification plant.

What precautions are taken by the authorities of your municipality to be sure that the drinking water is suitable for use? You will find a visit to a purification plant a most interesting experience.

PROBLEM II: How do farming communities protect their water supply?

The procuring of a steady supply of cool, clear, water, devoid of unpleasant taste and odour, and free from poisonous substances and living disease germs, (p. 66) is a matter of concern to dwellers in isolated houses. Let us consider how water reaches the wells on which they depend.

You have noticed in quarries, sand pits, and street excavations that frequently there are different layers or strata, (singular, stratum), such as sand, gravel, clay and rock. Some of these layers, like sand, sandstone and gravel, permit the passage of water and are said to be porous. Heavy clay and certain rocks, on the other hand, are non-porous. Frequently, however, water finds a way through the cracks in rock.

When rain reaches the ground, some of the water may flow over the surface and eventually reach a stream. If the surface layer is porous and not completely saturated, some may percolate through the soil until it reaches a non-porous stratum. This is how the soil water originates. The upper level of this water is known as the ground water-level or water-table.

In Fig. 47 the well C is a relatively shallow one dug in the porous soil and sub-soil; water rises in it to the ground water-level. Such a well is easily polluted; if a stable or privy is located on the higher ground above C the drainage of water is toward the well, and the water may rightly be regarded with suspicion.

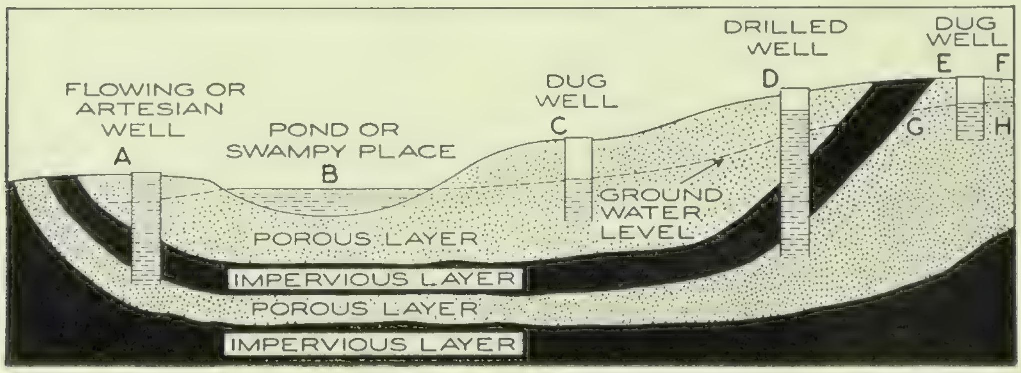


Fig. 47. Shallow, deep and artesian wells.

In the case of the well D, a hole is driven through the upper porous layer, through the impervious or non-porous stratum, which may consist of clay or shale, and finally into a second porous layer, possibly of sand, gravel, or sandstone. The level attained is approximately that of the water-table at GH. At B, where the water-table comes to the surface, a pond or swampy spot may be found.

The lower porous stratum receives its water at the surface EF and, due to the confining over- and under-lying non-porous layers, gradually becomes saturated. A well bored at A, to the depth indicated, taps water which would flow or gush

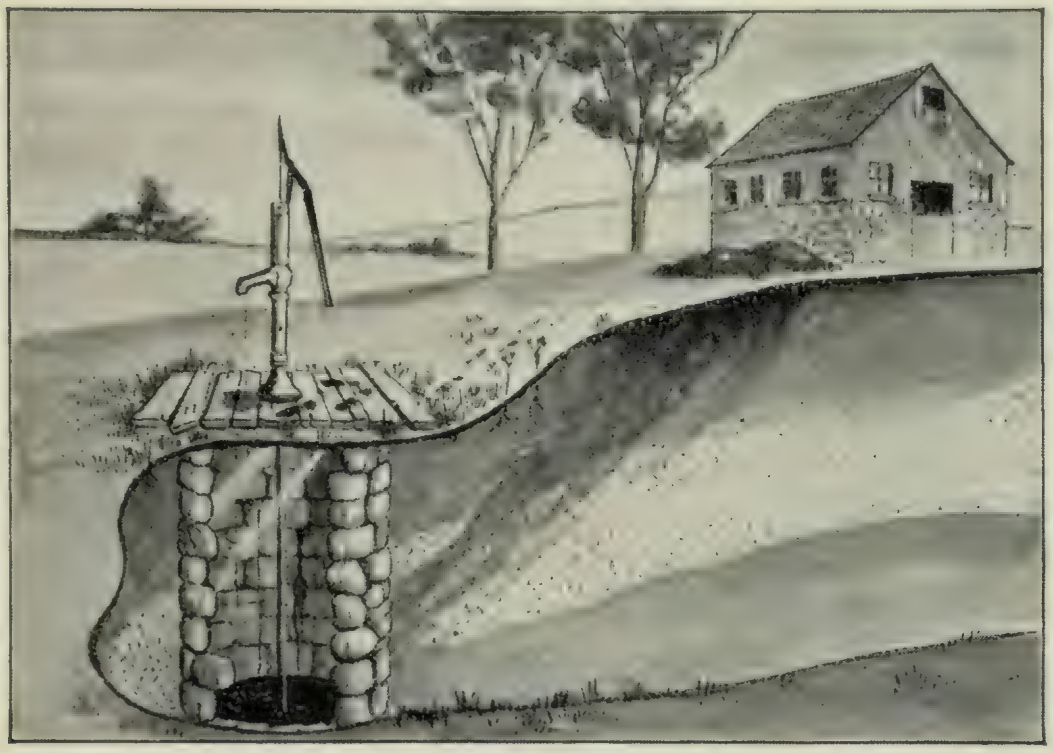


Fig. 48. Why should you be suspicious of water from a well like this?

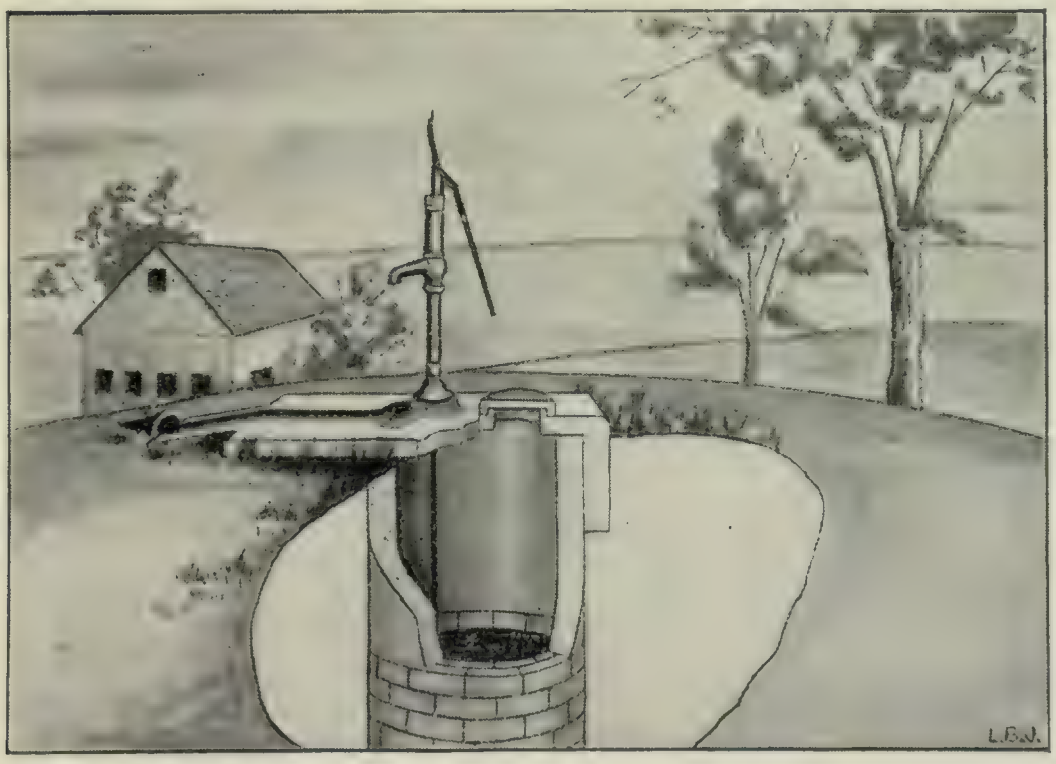


Fig. 49. Drinking water properly safe-guarded.

out. Such wells are termed artesian after the French province Artois where they have been in use for many years. Where the distance from A to E is considerable, a long time elapses before water entering the layer at the surface reaches the well. It is said that water may require fifty to a hundred years to traverse a distance of fifty miles under these circumstances.

Safe-guarding the water supply.

Artesian wells like that at A, and deep ones, such as that represented at D, are much safer than shallow wells on account of the large extent of soil through which the water must travel. If the sides of a well are not water-tight, water which is polluted may seep in. Again, if the top of the well permits the entry of water, contamination may result from material carried on the boots of people or on the feet of animals. A concrete or puddled-clay lining ten or twelve feet in depth and about six inches in thickness, and also a water-tight concrete top raised one or two feet above the level of the ground, should give reasonable security against these hazards.

In spite of these precautions, pollution may occur if the direction of drainage is towards the well. If this is the case, it is advisable to protect from contamination, as much as possible, the area in the vicinity, and to regard the water with suspicion until tests have been made. One may find out by the following procedure if drainage from a contaminated place is reaching the well. Pour a little coal oil or a solution of one part of fluorescein in a thousand of water, at the suspected spot. If the well water acquires the taste and odour of the oil, or is tinted green, pollution is indicated.

Water will be analyzed free of charge at the laboratories of the Provincial Analyst, Provincial Department of Health, Edmonton, Alberta. Before sending a sample of the water, one should write for bottles and instructions.

Treatment of suspected water.

The fact that water is clear and sparkling affords no guarantee of its suitability for drinking. In all cases of doubt, the water should be boiled or treated with either chlorinated lime or calcium hypochlorite in order to destroy germs. Take a half teaspoonful of chloride of lime and rub it up with a little water to the consistency of cream and stir well into a barrel of suspected water.

According to court decisions, the owner of a private water supply is liable if disease caused by water-borne germs can be definitely traced to his negligence.

How to make a model of an artesian well.

What corresponds to the lower impervious layer in Fig. 50? Where is the 'porous stratum'? Where are the upper 'impervious layer' and the 'artesian well'?

Exercises:

1. Why is it unwise to assume that clear, cold, sparkling water is suitable for human use without being boiled or treated with chemicals?
2. Explain why water from a mountain stream is more likely to be fit for drinking than water from a dug well.
3. How may water be freed from (a) dissolved impurities, (b) insoluble substances?
4. Why is distillation not used more commonly as a means of procuring water fit for drinking?
5. Explain why wells are frequently polluted by floods.

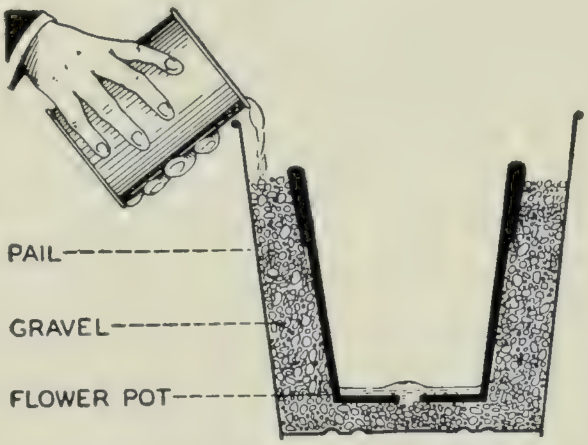


Fig. 50. A model of an artesian well.

E. MINOR STUDY: Provision must be made for transporting water from its source into the homes.

PROBLEM I: (a) Why does water flow through pipes?

Those who live in towns where the drinking water is obtained from a standpipe have noticed, no doubt, that a more rapid flow occurs at a cellar tap than at one in the bathroom. Suggest possible causes for the difference in rate. If it is noticeable in your house can you bring forward any evidence to show that it is not caused by a difference in the taps? Is there anything to show that it might be due to the fact that the taps are not at the same level? Construct a model by means of which you could test the value of the latter suggestion.

On what does pressure in water depend?

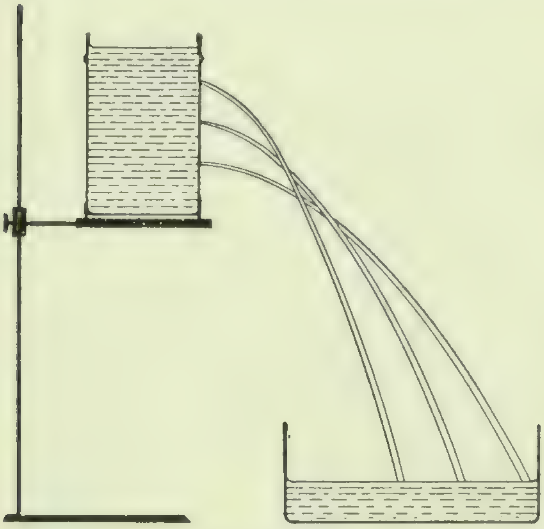


Fig. 51. Compare the force with which the water emerges with the depth of the aperture below the surface.

(i) Try the following experiment. Bore three holes, one vertically over another, in the side of a can. Keep the can filled with water and compare the distances to which the streams are projected. From which opening did the water emerge (a) with greatest force, (b) with least?

(ii) Enlarge the holes and into each insert a cork which carries a piece of glass tubing bent at right angles, (Fig. 52). Keep the can filled with water and notice the height to which the liquid rises in each tube. Compare these levels with that of the water in the container.

(If we pile bricks one upon the other, those nearest the bottom support more weight than those close to the top. We say that the lower bricks are under more pressure than the upper. Similarly, water near the bottom of the container has to bear the weight of the liquid above it. Hence, the deeper we go in water the greater is the pressure. Since A (Fig. 52) is lower than C, there is greater pressure at the former than at the latter level. We call the height of liquid above a certain level the head. Thus, when the can is kept filled, the head at A is the height AN. What is the head at B?).

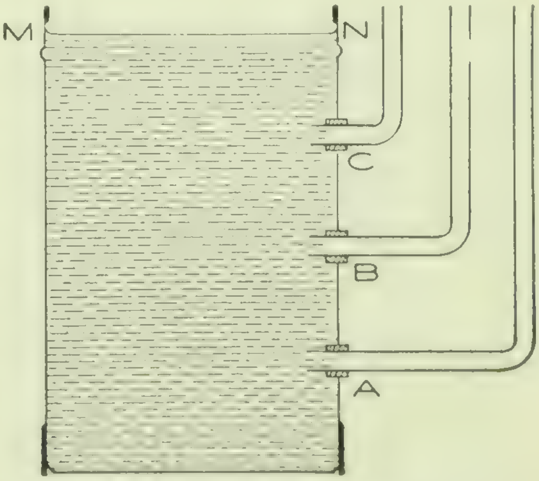


Fig. 52. How do the heights to which the water rises in the tubes compare with that of the water in the container?

We may compare the level MN with the level in the standpipe, and the openings at A, B and C with taps on different floors in the house.

It has been noticed that the levels in the three vertical tubes were nearly the same as that of the water in the can. This is an example of water 'seeking its own level'. Liquids 'seek their own level' only when the pressures at the two (or more) levels are the same.

(iii) Another interesting experiment may be performed to show that pressure in water depends upon the depth. Bend the stem of a thistle-tube twice at right angles, and then remove a part (Fig. 53). Fasten a rubber membrane tightly across the mouth of the tube and, by means of rubber tubing, connect the stem with a U-tube containing a little coloured water. Support the U-tube as indicated in the diagram.

Note the levels of the coloured water and then with the thumb press on the membrane. How are the levels affected? Alter the pressure of the thumb on the membrane and observe how varying degrees of pressure influence the water levels. It is clear that this piece of apparatus may be used to show differences in pressure.

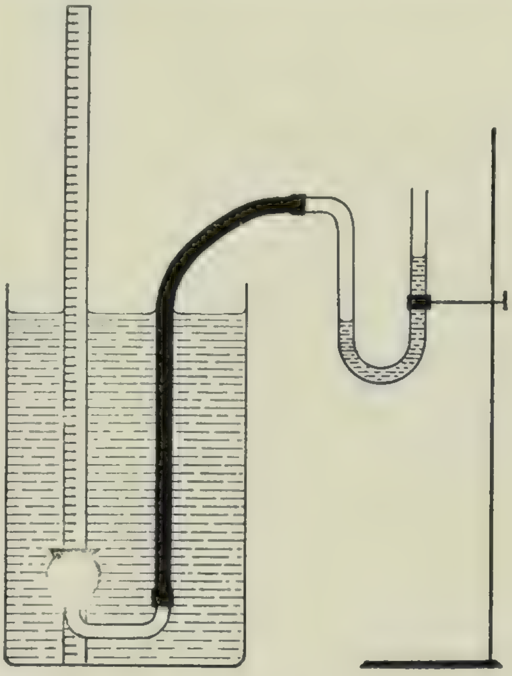


Fig. 53. Apparatus to show that the pressure of water depends upon the depth.

With rubber bands attach the thistle-tube to a metre stick. Lower the thistle-tube into a deep vessel nearly full of water. Observe the changes in the levels of the liquid in the U-tube as the depth of the membrane in the water is increased. To what conclusion do your observations lead you?

We have learned that water exerts a pressure and that this pressure changes with the depth. This has been found to be true for other liquids also.

The pupil may wonder if the pressure at a certain depth is the same in all directions.

PROBLEM I: (b) Does the pressure in a liquid depend upon the direction?

Mark the levels of the coloured liquid (Fig. 53) when the rubber membrane is at a certain depth. Keeping the centre of the membrane at the same depth, alter its position a number of times. Is there any change in the levels of the liquid in the U-tube?

PROBLEM I: (c) Does the pressure depend upon the surface area of the container?

If someone suggested that the pressure depended not only upon the depth of the water but also upon the diameter of the container, how would you try to prove or disprove the statement experimentally?

Is the pressure on a coin placed horizontally one foot below the surface of water in a pail greater than, equal to, or less than, that on the same coin similarly placed below the surface of a still lake?

PROBLEM II: How the waterworks department sends water to a house.

Purification does not end the responsibility of a waterworks department. Water must be made available for every house no matter how high the ground upon which it is built. In the case of fire, there must be sufficient pressure to throw jets of water to considerable heights.

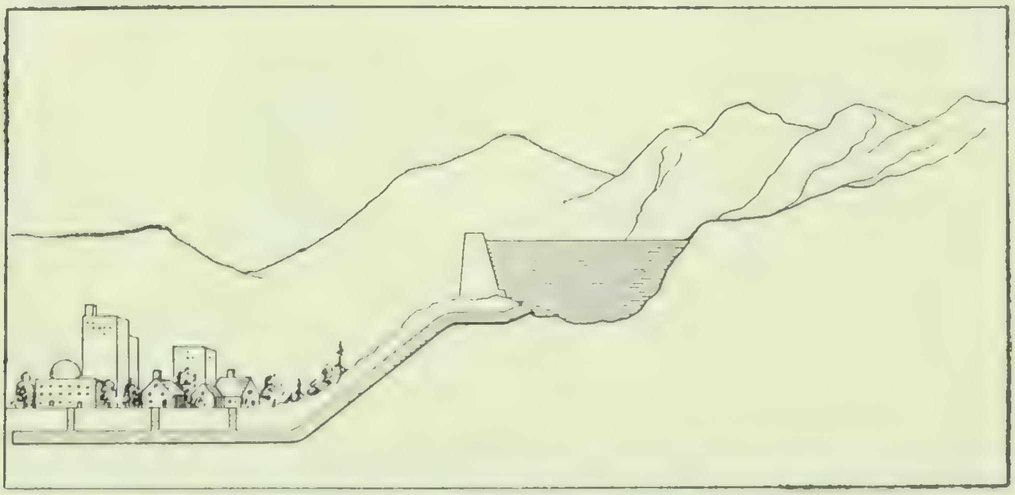


Fig. 54. A city supplied with water from a reservoir situated on high ground and fed by mountain streams.

When the reservoir is located on mountains, hills, or elevated land as at Halifax, St. John, Quebec, Calgary and Vancouver, little difficulty is encountered. The reservoir in the Catskills is sufficiently elevated to supply water to all buildings in New York City except those over three hundred feet high. In these buildings, special equipment is installed to provide the needed pressure.

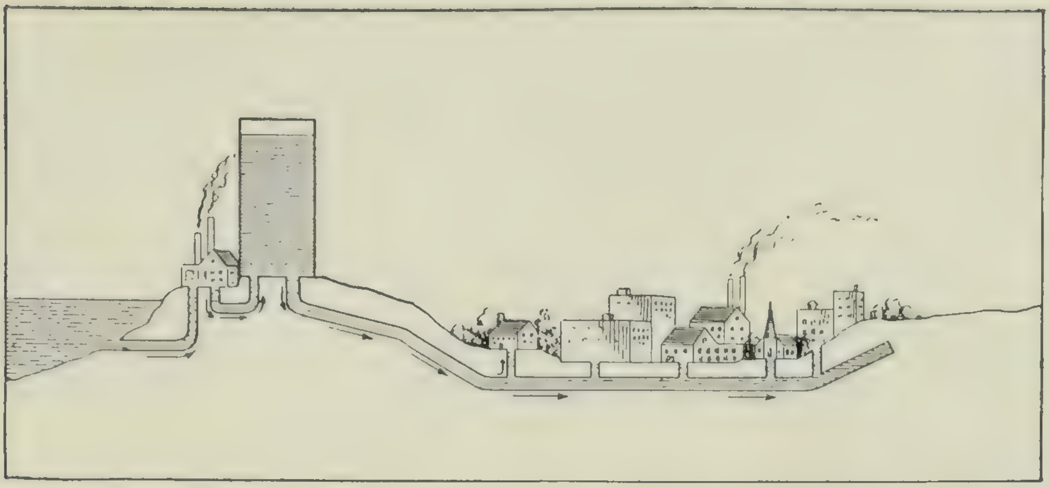


Fig. 55. This community obtains its water from a river or lake. The water is pumped into a standpipe.

Often the source of supply is below the level of the houses. When this is the case, the water is placed under sufficient pressure by means of pumps, as at Moncton, Montreal, Toronto, Ottawa, Edmonton and Regina. In other places, the water is first pumped into tanks, standpipes, or elevated reservoirs whence it flows into the distribution mains.

Weight and pressure.

When a pin is attracted to a magnet close by, we say that force is being exerted. There is another force which is so familiar to us that we seldom think of it as one. If we hold an object and then release it, the substance falls toward the ground. The object is said to be attracted towards the earth; the force of attraction is the weight of the object. If we hold the body in our hand, we must exert on it an upward force equal to its weight.

Let us imagine that on the floor is a pile of books placed one above another. Suppose that the total weight of the pile is 80 pounds and that the lowest book has an area of 40 square inches in contact with the floor. Then the pressure due to the books on each square inch of floor covered is two pounds.

Suppose that a man weighs 200 pounds and that his feet cover 50 square inches of floor. Then the average pressure due to the weight of the man is 4 pounds per square inch. If he were to stand on a wooden cube with a face of two square inches, what would be the pressure per square inch of the cube on the floor? (Disregard the weight of the cube.)

When we speak of pressure, we take area into account; weight is independent of area. The 200-pound man is attracted to the earth with a force of 200 pounds weight, no matter whether his feet are large or small. The pressure he exerts per square inch is obviously less if his feet are large than if they are small.

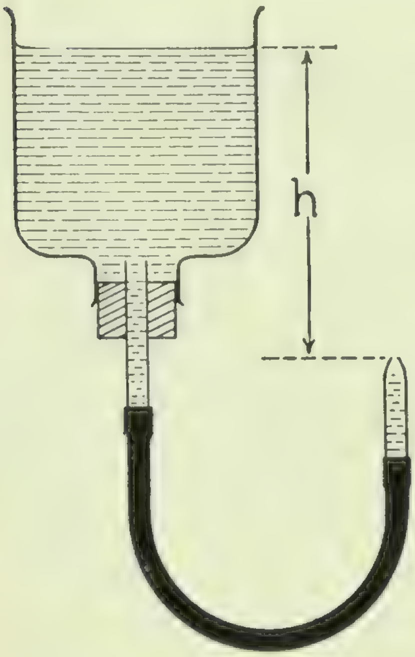


Fig. 56.

(1) How may the head (h) of water be altered, (Fig. 56)? Under what circumstances does the water emerge (a) with greatest force, (b) with least force?

(2) How is the public water in your community put under pressure?

(3) Examine a tap and find out how it works. How would you prevent a tap from leaking?

(4) What pressure in pounds per square inch is exerted on ice by a girl who weighs 90 pounds, if the area of the skate surface in contact with the ice is one-fiftieth of a square inch?

F. MINOR STUDY: Water is a compound composed of two elements, hydrogen and oxygen.

PROBLEM I: What is pure water?

Many of the objects we use are made up of a single substance. These elements, as we call them, include gold, silver, copper, aluminium and mercury.

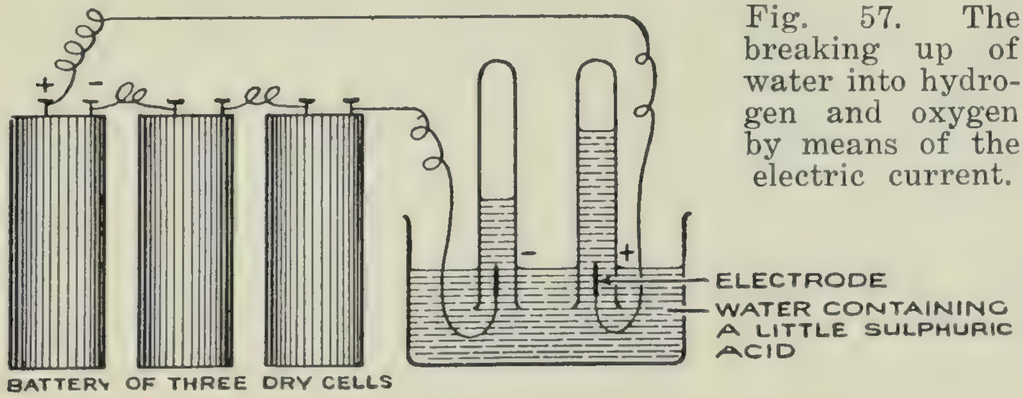
However, for every elemental substance in existence there are ten thousand compounds. These are made up of two or more elements, not merely mixed like a powder which is partly copper and partly aluminium, but united together in such a way that the untrained person would never suspect their presence. Table salt, for instance, is a compound in which two elements are united or combined. Who would suspect that these two elements are sodium, a silvery metal so soft that it may be cut like butter and so light that it floats on water, and chlorine, a greenish-yellow gas used in the struggle against disease-causing germs and in the warfare of man with his fellow-man?

Is water an element or is it formed by the union of elements? The ancient Greeks considered that earth, air, fire and water were elements, but in comparatively recent times it was discovered that water is really a compound. Let us see how the liquid is broken up into the elements which compose it.

PROBLEM II: What is the composition of water?

Set up the apparatus shown in Fig. 57. The platinum electrodes under the test-tubes are soldered to the connection wire, and the parts of the latter in contact with the water are coated with shellac. If platinum electrodes are unavailable, carbon ones obtained from old dry cells may be employed, (Fig. 58). At the outset, the test-tubes are filled with water.

After connection has been made, observe the ends of the electrodes. Is there any indication that the water is being affected by the electric current? Water is an extremely poor conductor of electricity but this difficulty is overcome by adding a few drops of sulphuric acid. At the end of the experiment there is as much sulphuric acid as at the beginning; its function is to enable the current to pass through the water.


+
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ELECTRODE
WATER CONTAINING A LITTLE SULPHURIC ACID
BATTERY OF THREE DRY CELLS

Fig. 57. The breaking up of water into hydrogen and oxygen by means of the electric current.

What effect has the passage of the current on the water? At which of the terminals or "electrodes" is the greater amount of gas set free? Compare the relative amounts of the gases in the two test-tubes after a reasonable interval. What is the colour of each gas?

When the first test-tube is filled with gas, remove it, being careful to hold the thumb tightly over the top, In its place put another test-tube filled with water. Apply a lighted match to the mouth of the test-tube you removed and describe the result.

Light a thin piece of wood and then extinguish the flame. Place the glowing splint in the mouth of the test-tube in which the gas collected more slowly. Describe what happens.

When sufficient gas has been obtaineed, disconnect the dry cells.

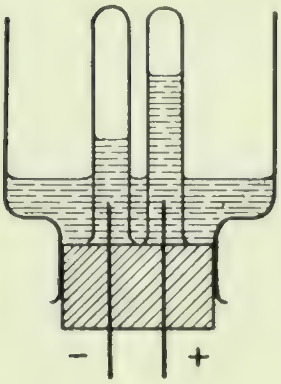


Fig. 58.

We have seen that when an electric current is passed through water containing a small amount of acid two colourless gases are formed. They behave differently in the presence of a burning piece of wood; the one which produced a ‘pop’ when ignited is called hydrogen, the other, which re-kindled the glowing splint is known as oxygen. For every volume of exygen obtained from the water two volumes of hydrogen were formed.

You may be interested to learn that hydrogen is the lightest substance known. If you can collect enough, try to pour it downwards from one test-tube to another. Find out whether or not you succeeded. Try to pour it upwards. How could you prove that you were successful? Because of its lightness, the gas has been used in airships and balloons, but because it forms an explosive mixture with air, the heavier but incombustible helium is preferred. Recall the Zeppelin disaster of 1937.

Later, we shall devote more time to the study of oxygen.

TOPIC III—AIR

UNIT 3. MAJOR STUDY: Air is an essential factor in the environment of all living things.

A. MINOR STUDY: Air is everywhere.

Let us imagine creatures moving about on the sand or mud at the bottom of the sea. These imaginary animals may jump short distances into the water above them but they have never seen the surface. Indeed, so accustomed are they to their water invironment, the only one they have ever known, that few if any realize that they are continually immersed in liquid, or indeed that any other existence is possible.

Compare our own environment with that of these aquatic animals. We walk on the floor of a great gaseous ocean, the ill-defined surface of which is from 200 to 500 miles above our heads. Until modern times the length we could travel with safety through the air was merely the distance we could jump. It is true that, because of our intelligence and experience of brief immersions in water, we can imagine other modes of life, yet so accustomed have we become to the gas which surrounds us that we think of it only when it is moving with unusual speed or when we are violently deprived of the supply on which, from minute to minute, our lives depend.

The gaseous mantle in which the earth is wrapped is called the atmosphere.

PROBLEM I: (a) Does air occur in soil?

Demonstration of the existence of gas in soil.

Obtain two tin cans A and B in the bottom of one of which (A) there are holes bored. Place soil in the cans until it is within a few inches of the surface. Tap the containers until the soil is packed as closely as in its original position in field or garden. Add water quickly to B and note what happens. Set A on a plate containing water; then pour water quickly on the surface of the soil. Notice where the bubbles are formed this time. Account for (a) their production, (b) their location.

The gas observed does not differ greatly in its composition from ordinary air. Where is it held in the soil? Will a soil saturated with water contain air?

Suggest a method of finding the volume of air in a sample of garden soil.

Soil is composed of particles in which there are spaces. The sizes of these depend upon the coarseness or fineness of the particles, just as the spaces between apples in a barrel are large or small according to the size of the fruit. The spaces are not empty but contain varying amounts of water and air.

For most plants the air in the soil is as necessary as the water. In a poorly-drained soil, where the spaces are filled with water to the exclusion of air, few plants can thrive because their roots are deprived of oxygen. If there is satisfactory under-drainage, the water passes downward through the soil, and air from the atmosphere enters to take its place. Hence, a well-drained soil is also a well-aerated one. Cultivation gives soil an open texture and thus aids in its aeration.

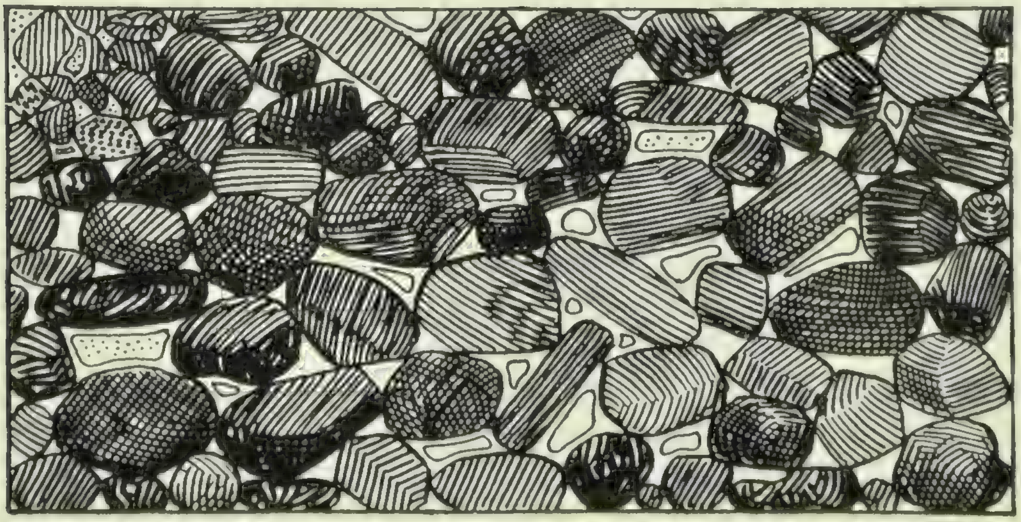


Fig. 59. Soil particles greatly magnified.

The pupil may inquire about plants the roots of which are completely immersed in water. If these are aquatic plants, they possess special features which fit them for their environment; if they are land plants growing in culture solution, (p. 303) either the water is aerated artificially, or there is a sufficient exposure of water surface to the air to permit adequate quantities of oxygen to enter solution.

In the soil, numerous armies of bacteria live on dead plant or animal matter and bring about its decay. This is a most useful work, for on it, to a large extent, the fertility of the soil depends. Unless there is a reasonable supply of air in the soil, these beneficial bacteria do not thrive.

PROBLEM I: (b) Does air occur in water?

You will remember that we discussed water as a solvent of such substances as sugar and salt. Air is dissolved in water in the same way that sugar is dissolved in tea. Gently warm a beaker filled with tap water. Note that bubbles of gas rise up through the water. These bubbles become larger as they near the surface. Why? (Hint: Pressure increases directly as the depth.)

PROBLEM II: Of what is air composed?

We have learned that the commonest of all liquids is a compound of two invisible gases. It would be of interest to find out something about the composition of the gas which continually surrounds us. A somewhat indirect approach is necessary.

Is air affected when iron rusts?

Shake some iron filings into a gas-jar which has been wet inside. (Instead of filings, steel wool to a depth of one inch may be used. This should be washed with carbon tetrachloride to remove adherent grease, and then moistened with water.) Pour a little water into a trough and in this invert the jar with its metal and air. Also, invert beside it a second gas-jar containing air but not the iron. Do not permit air bubbles to escape. Mark the inside and outside levels of the water with rubber bands. Examine the levels and the iron from day to day. (Test-tubes, instead of gas-jars, may be used, as in Fig. 60).

Did an alternation of level take place in the gas-jars or test-tubes? If there was no change of level in the jar lacking iron, it may be removed. Why was this jar used? Could we have connected an alteration of level in the other gas-jar with the presence of the iron if this one were not inverted also? When no further change in the level of the water occurs, add water to the trough until the levels inside and outside bear the same relationship to each other as they did at the beginning of the experiment.

Mark the water level in the jar or tube. If you have used the former container, slip a glass plate across the open end and remove the vessel from the trough. If you have used a test-tube, place the thumb across its mouth before withdrawing the tube from the water.

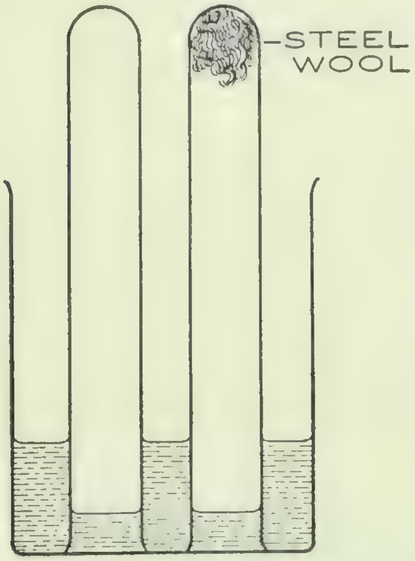


Fig. 60. Does air play a part in the rusting of iron?

Insert a lighted splint into the vessel and also into the one of the same size containing ordinary air. Is there any evidence that a change has taken place in the air which was in contact with the metal?

Find the volume of the container by filling it with water from a graduated cylinder. In a similar manner find the volume of the part of the air which disappeared. Express the latter volume as a percentage of the former.

Describe the change in the appearance of the iron.

Devise an experiment by which you could find out if filings would rust in the gas remaining after moist iron has been left in contact with an enclosed volume of air for a considerable period.

Let us summarize what we have learned: (a) when iron is permitted to rust in an enclosed volume of air, about one-fifth of the gas disappears; (b) the four-fifths remaining differs from ordinary air in that combustible substances are unable to burn in it.

If you were to weigh the original iron and the rusted metal which remained at the conclusion of your experiment, you would find that the latter was the heavier. The fraction of the air which disappeared, united or combined with the iron during the formation of the rust.

A question may occur to the thoughtful pupil—"Does any part of the air disappear during burning as it does during rusting? "

What substances burn, does any of the air disappear?

It would be rather foolish to attempt to answer this question experimentally by using an unlimited quantity of air. Let us imprison a small amount and try the effect of burning a candle in it.

Pour water into a trough to a depth of several inches. Float on the water a little dish, such as a crucible, containing a short length of candle. Light the candle and invert over it a large sealer or other suitable container. Make sure that no air escapes while the sealer is being placed in position. Observe the candle and water level closely, and describe what you see.

When the candle flame is extinguished, do not touch the apparatus until the level of the water becomes stationary. Then pour water into the trough until the levels bear the same relationship to each other as they bore when the jar was inverted. With a rubber band, mark the height of the water in the sealer. What percentage of the original air has disappeared?

Slip a cover over the mouth of the sealer and remove the jar from the water. Test the gas remaining with a lighted splint. Does this residual gas support combustion?

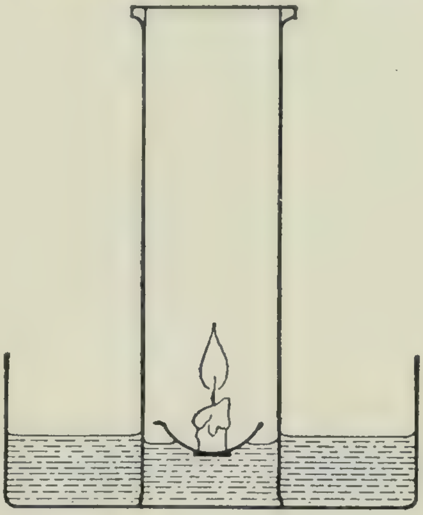


Fig. 61. Does a part of the air disapppear when a candle burns?

When a candle burns, it forms water vapour and another gas. The former condenses but the latter must be removed if we desire to find what fraction of the air is used up during burning. A considerable amount of this gas dissolves in the water. It will be removed much more effectively if, instead of water, limewater is used.

As you have observed, a candle can burn only for a limited time in an enclosed volume of air. A part of the air is removed and the remainder does not support combustion.

What gas enables substances to burn?

That part of the air which enables substances to burn and which takes part in the rusting of iron is called oxygen. You will recall that this is one of the two gases, which, when united, form water.

What is the inactive gas in air?

The gas remaining when rusting is completed or when the candle flame is extinguished is largely nitrogen. (It may be mentioned here that a candle burns so feebly that the flame dies before all the oxygen is used up.)

Unlike water, air is not a compound. It is a mixture of nitrogen, oxygen, water vapour, and a number of other gases. However, the greater part is composed of the two first mentioned; each hundred cubic feet contains seventy-seven of nitrogen and twenty-one of oxygen.

From what sources do we get carbon dioxide?

The effect of heat on charcoal.

Place a little charcoal on a deflagrating spoon or ordinary iron spoon and heat it in a flame. Observe any change.

A substance produced when charcoal burns.

Heat a piece of charcoal on a deflagrating spoon provided with a gas-jar cover, (Fig. 62). Lower the spoon into a gas jar containing some limewater. When the burning ceases, shake the jar vigorously. Describe the change in appearance of the limewater. Perhaps you think that the change in the limewater could be brought about by shaking the solution in ordinary air. Perform the little experiment necessary to settle the matter.

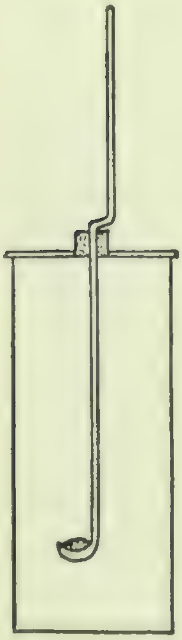


Fig. 62.
Deflagrating spoon in a gas jar.

Charcoal is a substance composed largely of the element carbon. When it burns in air, a colourless gas called carbon dioxide is formed. This gas is absorbed by limewater and, as you observed, produces in it a characteristic milkiness.

You will remember that we referred to a gas formed when a candle burns, and that we suggested the use of limewater to absorb the substance quickly. A candle is a compound which contains carbon; during the combustion of the candle this substance gives rise to carbon dioxide.

Substances which contain carbon.

Place a little sugar in a dry test-tube. Holding the tube horizontally, heat gently. Describe the residue.

Similarly heat small quantities of wood, starch, flour and meat.

Do the residues produce carbon dioxide when heated strongly on a deflagrating spoon?

Carbon in various states of purity is obtained when substances of plant or animal origin are heated. When these substances are burned, one of the products of combustion is the gas carbon dioxide.

(It should not be thought that the only substances which contain carbon are those derived from plants or animals. Limestone and baking soda contain the element; the diamond is a crystalline form of carbon of great purity.)

Another source of carbon dioxide.

In addition to the carbon dioxide which enters the air whenever carbon-containing substances are burned, there is another important source of supply. Is carbon dioxide present in exhaled breath?

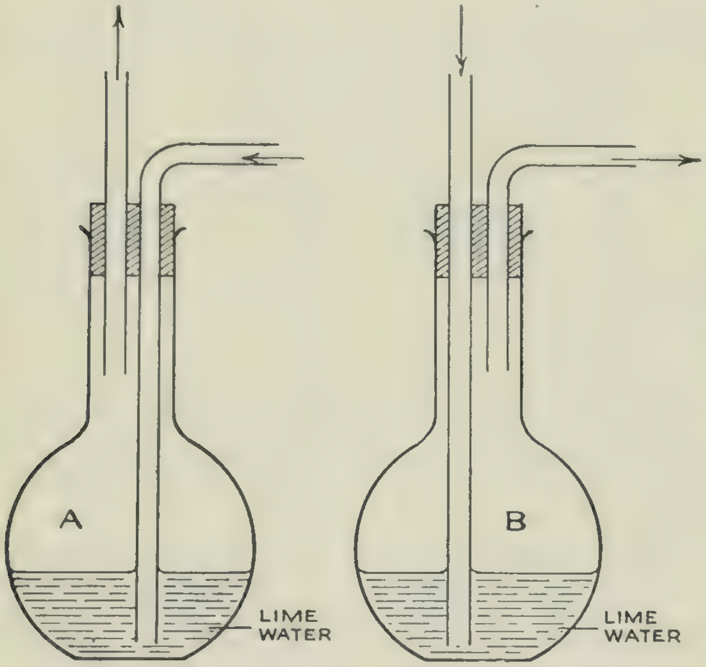


Fig. 63. Comparison of the amounts of carbon dioxide in air and in exhaled breath.

Carry out a simple experiment to demonstrate the presence or absence of carbon dioxide in exhaled breath.

There is, of course, the possibility that the carbon dioxide you have detected in exhaled breath is merely that which was present in the air drawn into the lungs.

Comparison of the amounts of carbon dioxide in the air and in exhaled breath.

Set up the apparatus sketched in (Fig. 63). The two flasks contain equal volumes of limewater; the long tubes dip the same depth below the surfaces. Alternately inhale through the short tube of A and exhale through the long one of B. Why does air pass through the solution in A?

In which flask does a change occur first? What is your inference?

It has been found that, neglecting water vapour and certain other gases present in small quantities, inhaled and exhaled air have roughly the following composition:

Gas analysed	Percentage of nitrogen	Percentage of oxygen	Percentage of carbon dioxide
Inhaled air	79	21	0.04
Exhaled air	79	16	4.40

Further study of the properties of carbon dioxide.

In order to obtain reasonably large quantities of carbon dioxide in a fairly pure state, it is necessary for us to use another method of preparation.

Preparation of carbon dioxide.

Set up the apparatus shown in (Fig. 64). The flask contains limestone, or marble, or baking soda, and some water. Dilute acid is added slowly through a thistle-tube. Effervescence takes place because quantities of carbon dioxide are produced. Why should the end of the thistle tube dip below the water-level? What gas will be swept out of the flask and delivery tube by the carbon dioxide? Why is it inadvisable to place the end of the delivery tube under the gas-jar during the first few minutes? Fill several jars, slip a glass plate across the open end of each and set the container, covered thus, in the vertical position on the bench.

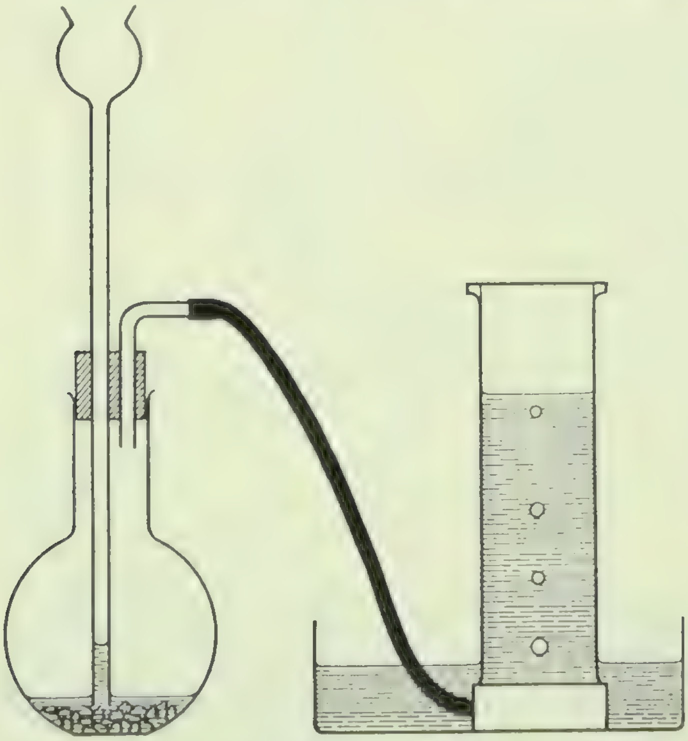


Fig. 64. The preparation of carbon dioxide.

Properties of carbon dioxide.

Describe the colour and odour of carbon dioxide.

Collect carbon dioxide in a test-tube inverted over water. When the test-tube is about three-quarters filled with gas, cover its mouth with the thumb and remove it from the dish. Shake the water and gas together vigorously. Is there any pressure on the thumb? In what direction is the pressure exerted? What inference may be made concerning the solubility of carbon dioxide in water?

Does carbon dioxide support combustion?

What is the effect of passing the gas through limewater (a) for a minute or two (b) for a longer time? After the murkiness disappears, pour a little of the liquid on a clean watch glass. Examine the glass after the water has evaporated. Boil a little of the clear liquid in a test-tube. Describe what takes place.

Uncover a gas-jar containing carbon dioxide. Invert the jar and place just below its mouth a lighted match. What is the effect on the flame? Suggest a reason why the flame was extinguished. In what direction did the gas flow?

Now hold a lighted match just over the mouth of a jar of carbon dioxide. Is there any indication that the gas flowed upwards? Which is the denser—air or carbon dioxide?

Exercises:

1. Give an explanation of the following trick at one time played by unscrupulous sellers of quack medicines.

With much fervour they would describe certain ailments which caused, they asserted, a 'bad breath'. Anyone in the audience might have his breath tested free of charge. Some gullible person would go up to the front, and, in the presence of the crowd, would bubble his breath through the 'water' provided. A milkiness would be produced and much sympathy for the "sufferer' would be excited.

However, there was still hope; a dose of the wonderful medicine would bring results. The 'patient' would swallow a mouthful and again test his breath. How rapid, how complete, was the cure! No cloudiness appeared in the 'water'; a well man was restored to his family.

2. Before descending into a well a man lowered into it a lighted lantern. What was the purpose of this precaution?

ENRICHMENT SECTION, NUMBER 4.

Deep sea diving.

Compressed air, like ordinary air, is a mixture of approximately 78% nitrogen, 21% oxygen and 1% other gases.

In breathing, the nitrogen is mostly exhaled. But under pressure, as in a diving suit under water, much of it passes from the diver's lungs into the blood stream, from whence it is deposited in the various tissues and liquids of the body. When external pressure is released, the nitrogen returns again to a gaseous state, causing bubbles to appear in the blood and other tissues where nitrogen has lodged.

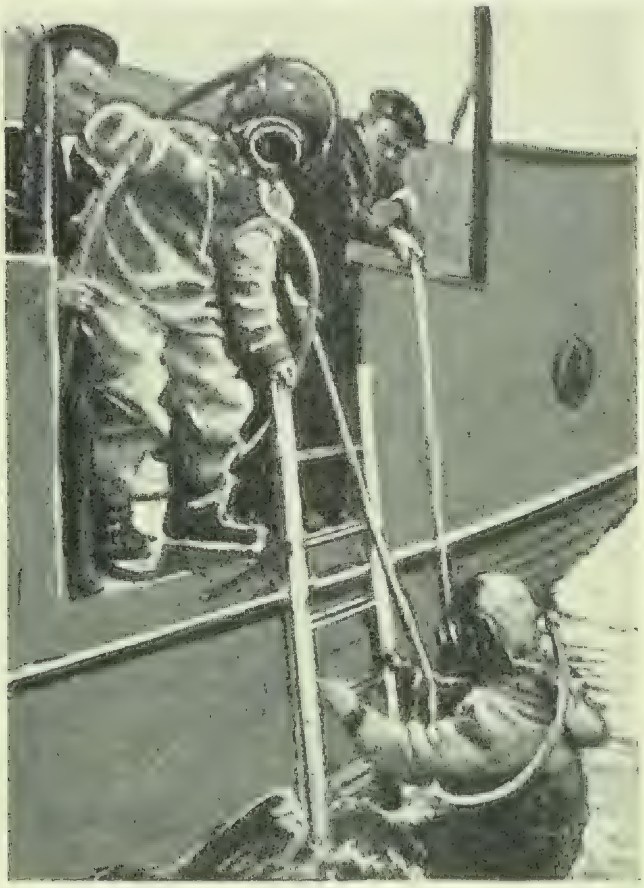


Fig. 65. The diver's costume weighs about 150 pounds, but so buoyant is the water that he has to put his feet under the ladder rungs to pull himself down.

As the diver returns to the surface, he must come slowly enough to permit the escape of these bubbles, otherwise they will exert sufficient pressure to tear the tissue or rupture the blood vessels. Divers term this compressed-air illness "the bends". Nitrogen is slow in returning to its gaseous form, so the diver has to be raised in stages and finally has to be placed in a decompression chamber.

Oxygen under pressure burns the tissues away very rapidly. The oxygen content of the air remains in the same ratio of 21% oxygen to 78% nitrogen, but under pressure it burns tissues away so rapidly as to cause great fatigue.

Helium is an inert gas and can be breathed without ill effects. Being much lighter than nitrogen, it saturates the tissues more quickly than nitrogen does. Also, it comes out of solution in less time than is required by nitrogen. When pure helium, with enough oxygen to sustain life, is used, decompression requires but one twenty-fourth of the time required for ordinary air.

Breathing such an artificial atmosphere on December 1, 1937, Max Gene Nohl, the broadcasting diver, broadcast from a depth of four hundred and twenty feet of water in Lake Michigan.

Exercises:

1. Cut out pictures of divers and paste them in your scrapbook.
2. If water weighs 62.5 pounds per cubic foot, and the pressure increases directly as the depth, find the pressure on each square foot of the surface of Nohl's diving suit while he made his broadcast.
3. Learn all you can about deep-sea diving exploits.

Some physical properties of air.

We have already made use of expressions such as "an enclosed volume of air" and "imprisoned air". These imply that air occupies space. No doubt we should have a deeper conviction that the invisible, odourless gas around us is really a substance which takes up a certain amount of room if we were to perform some experiments.

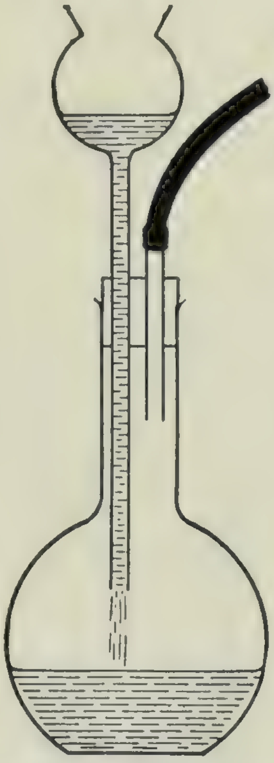


Fig. 66. What is the effect of closing the rubber tubing?

PROBLEM III: (a) Does air occupy space?

(i) Push a drinking glass mouth downwards into a pail of water. While doing so, allow no bubbles of air to escape. Does the water occupy the whole of the glass? How is the height to which the water rises affected by the depth to which the glass is immersed? Is it possible, by immersing the glass to sufficient depth, to make the water occupy all of it?

(ii) Set up the apparatus sketched in Fig. 66. Pour a little water into the thistle-tube. Does it enter the flask easily? Hold the rubber tubing tightly and pour in some more water. Does it flow freely into the flask? Release the rubber tubing and note the effect.

(iii) Replace the short rubber tube in the apparatus of (ii) above by a longer piece. Allow the free end of the tube to dip below the surface of water in a dish. Pour some water into the thistle-tube. Is there any evidence that something is escaping from the flask? Why did water not enter the flask when the end of the rubber tubing was held tightly?

How would you obtain some air from one room and carry it into another?

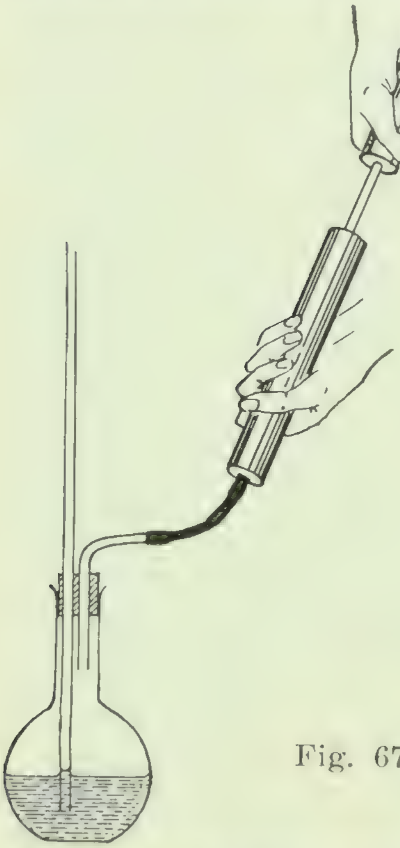


Fig. 67.

(iv) Pour water in a flask until it is about half full, (Fig. 67). Fit the flask with a cork in which there are two holes, through one of which is inserted a glass tube of sufficient length to permit an end to dip below the surface of the water, and through the other, a short glass tube. To the outer end of the latter attach a piece of rubber tubing. By means of a bicycle pump, force air through the shorter of the two tubes. Observe the result. What conclusion may be drawn?

We have seen that air, like solids and liquids, occupies space. However, it is possible, as we have observed, to 'crowd' air or, in other words, to compress it. (Liquids are very incompressible and solids still less.) Also, we have learned that, like liquids, gases can flow.

Often the expression 'light as air' is heard. It seems difficult to believe that gases can have weight.

PROBLEM III: (b) Has air weight?

(i) Fit a flask with a rubber stopper containing one hole, through which passes a piece of glass tubing. To this attach a short piece of rubber tubing. Put this apparatus and also a spring clip on one side of a sensitive balance; on the other side place sufficient weights and pieces of paper to act as a counterpoise. Remove the flask from the balance and into it force air by means of a bicycle pump. By means of the clip, prevent the air from escaping. Replace the apparatus on the balance. Has the additional air forced into the flask any weight? If an exhaust pump is available, remove air from the flask and find if there is an alteration in weight.

(ii) Obtain an electric light bulb from which the air has been exhausted and counterpoise it on a sensitive balance. Remove the bulb from the balance and file through the glass to permit the entrance of air, being careful to allow the filings to fall on the balance pan. Replace the bulb on the balance. Has there been any change in weight?

The weight of air is far from negligible. To have a pound of air one would need only twelve cubic feet of the gas; in a classroom 32 feet long, 23 feet wide, and 12 feet 3 inches high, the air has a weight of approximately 750 pounds.

Because of their weight, solids and liquids exert pressure. We have satisfied ourselves that air, light as it seems, possesses weight also. Are we, dwellers at the bottom of an ocean of gas, subjected to pressure as fish are by the water above them?

PROBLEM III: (c) Does air exert pressure?

(i) Fasten a piece of thin rubber sheeting tightly across the funnel of a thistle-tube. Attach a short rubber tube to the end of the stem and with the mouth remove as much as possible of the air in the thistle-tube. Tie a string around the rubber tube to prevent the air entering. (Fig. 68).

Has the shape of the rubber sheeting altered? If so, how? What is the probable cause of the alteration? Point the thistle-tube in different directions. Does the direction in which the tube points affect the shape of the rubber? Why was it necessary to remove the air from the tube?

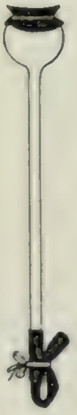


Fig. 68.

(ii) Fill a drinking glass with water and over it place a piece of cardboard, taking care that there are no air bubbles between the cover and the surface of the water. Turn the glass upside down. What evidence have you that the air is pressing upward on the cardboard?

(iii) Boil an egg until it is hard. Remove the shell. Obtain a bottle with a neck slightly too narrow to admit the egg. Boil a small amount of water in the bottle for three or four minutes. Remove the source of heat. Insert the egg into the neck as far as it will go. Explain what happens.

(iv) Boil a little water in a maple syrup can for five or ten minutes.

Remove the can from the heat and insert a cork before the boiling has had time to subside. The apparatus should now be air-tight. Describe what happens to the can. Does the air exert pressure?

(Steam from the boiling water expelled the air from the can. When the can cooled, the steam inside condensed. If the can is not quite air-tight, it should be cooled quickly with cold water.)

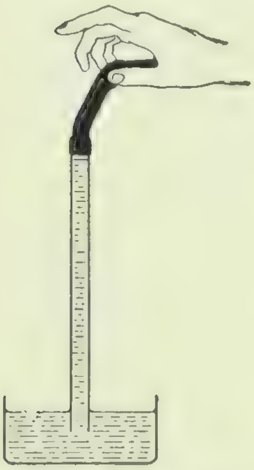


Fig. 69. Explain why the water does not run back into the dish.

(v) Hold a glass tube in water. When the liquid has risen in the tube place a finger tightly over the upper end. Remove the tube from the water. Does the water run out of the tube? If it does not flow out, give an explanation.

(vi) Attach a short length of rubber tubing to one end of a glass tube such as was used in (v) above. Insert the other end in water. With the mouth remove the air from the tube. Why does the water rise? When the glass and rubber tubes are full, close the rubber tube with the fingers. Leave the end of the glass tube just below the surface. Why does the water not run back?

(It may be found more convenient to fill the combined tubes by completely immersing them in a deep vessel of water than by withdrawing air with the mouth. Another device may be used. Close the rubber tube by means of string or a clip. Invert the tube and pour water in until it is filled. Then close the open end with the thumb and invert the tube in water. Remove the thumb.)

Before we withdrew air from the tube (Fig. 69), the pressures inside and outside were equal. Hence, there was no movement of the water inward or outward. As soon as we removed some air, the pressure in the tube was reduced below that of the atmosphere. Immediately, the excess pressure forced the water inside. If we were to release our hold on the rubber tube, the pressure on the surfaces of the water in both tube and trough would be the same, namely that of the atmosphere. As a result, the water would run down until the inside and outside levels were equalized.

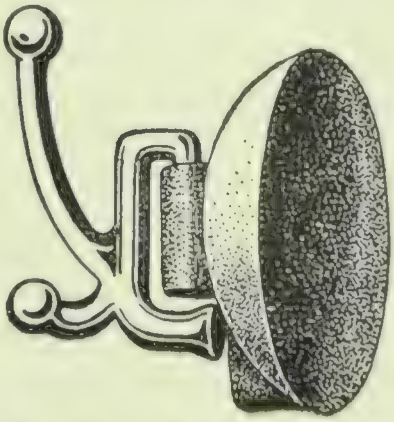


Fig. 70. A useful little device in which advantage is taken of air pressure

Exercises:

1. When a girl was drinking orangeade, a seed entered the straw she was using and prevented the passage of the liquid. Explain why the tube was flattened.

2. A drinking glass was removed from hot water and set mouth downward on a piece of thin oilcloth. Why did the oilcloth bulge into the glass?

3. Fill a milk bottle with water and then hold it upside down. Describe how the water flows out and give an explanation.

4. When campers wish to obtain condensed milk from a can, they frequently pierce two holes in the top. The milk is poured through one of these. What is the use of the other one?

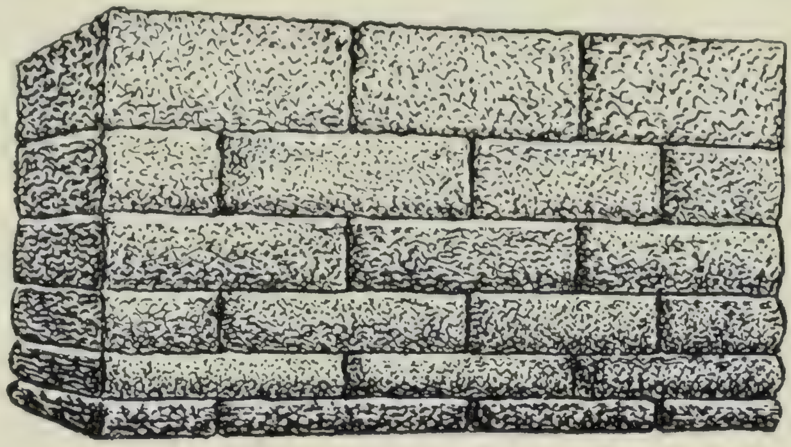


Fig. 71. We may compare the atmosphere with a wall constructed of rubber bricks. Where is the compression greatest? Where is it least?

B. MINOR STUDY: All living things require air.

PROBLEM I: How does air sustain life?

In previous grades in Health and in Elementary Science, you have had occasion to study cells; those little 'bricks' of which plants and animals are built. In these cells, substances derived from food meet oxygen and are 'burned'. As a result of this oxidation, organisms, both great and small, get the energy necessary for their activities. Another result is the formation of 'furnace ashes' or waste products, among which are carbon dioxide and water.

If air were excluded from a cylinder in an automobile, the gasoline vapour could not be exploded and no energy would be obtained. Similarly, our food could not supply us with heat and energy if we could not obtain the oxygen necessary for the 'burning' which goes on in the cells.

Respiration is not merely the inhaling and exhaling of gas, a process properly referred to as 'breathing'. It involves the oxidation of substances in every living cell.

PROBLEM II: How do plants obtain air?

Examination under the microscope of the skin of a leaf.

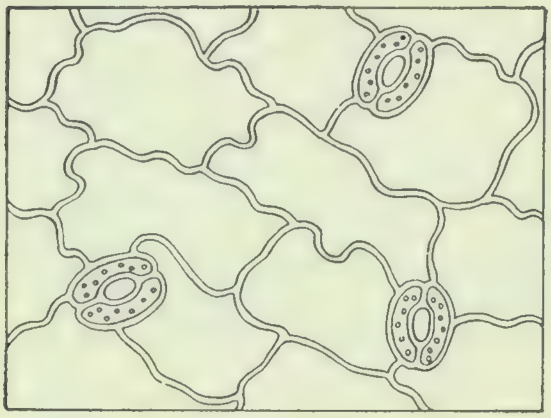


Fig. 72. A small portion of the skin of a leaf. The openings are stomata; the sausage-shaped structures are called guard cells.

With a razor, remove a small portion of the skin off the lower side of a lily or peony leaf. Put the strip on a microscope slide with the lower side next the glass. Add a drop of water and then over skin and water place a cover glass. Examine the skin under the low power of the microscope.

Those little 'fenced-in' areas you see are the surfaces of cells. When the microscope was invented, the first cells examined were the dead ones in a thin slice of cork. The regular arrangement, suggesting a piece of honeycomb, gave rise to the name 'cell'. Cells are not of regular shape; there is a great variety. It is well to realize that cells have depth in addition to length and width. Surrounding each cell is a wall.

Notice the little openings in the skin of the leaf. Each is called a stoma, (plural, stomata; Gk. *stoma*, mouth). Make a drawing of a stoma and a few surrounding cells.

The plant obtains air through these openings. In other ways also they are of use to it.

PROBLEM III: How do birds and mammals obtain air?

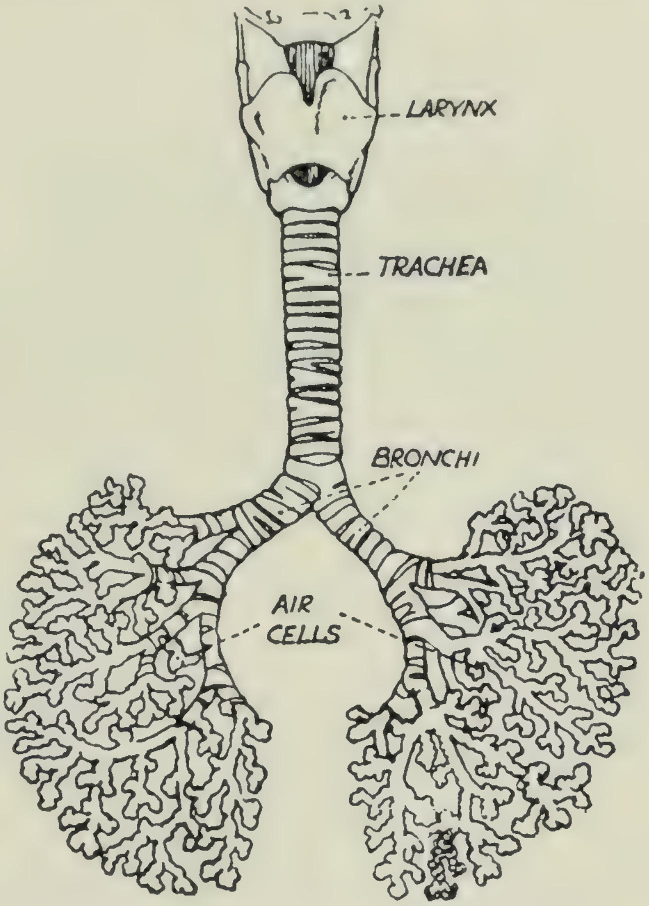
The path along which air travels to the lungs.

Air enters the passages of the nose, where it is warmed by numerous blood vessels, slightly moistened by the mucous lining, and partially freed from dust by little hairs. Thence it passes to the pharynx, that part of the throat which communicates with the mouth as well as with the nose, and which extends downward to the junction of the gullet and larynx.

Because of this use of the upper part of the alimentary canal as an air passage, it is possible, although unwise, to obtain air through the mouth.

From the pharynx, the air passes through the voice-box, 'Adam's apple', or larynx, as the wind instrument of the body is variously called. This is situated at the upper end of the windpipe or trachea.

The lower end of the windpipe branches into two tubes known as bronchi (singular, bronchus). Each of these enters a lung, where it divides and sub-divides a great many times. Each branchlet ends in a tiny air sac, which is surrounded by a network of capillaries. We may imagine how numerous these sacs are when we learn that in the average adult they would occupy a hundred square yards if laid down flat. It is because they contain so many little air bags that the lungs are light and spongy. The function of the sacs is obviously to bring closely together the maximum amounts of air and blood.



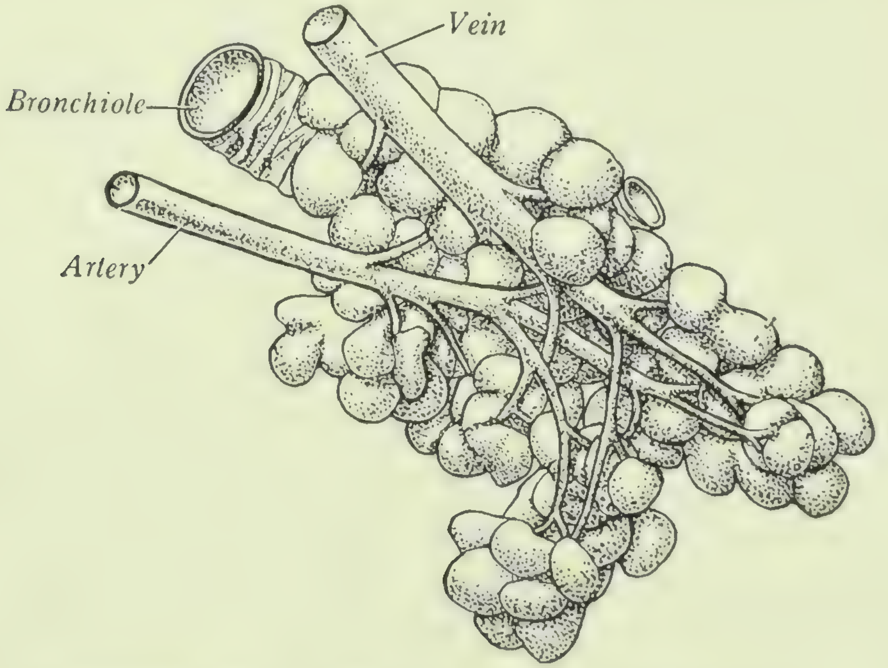
From "Everyman in Health and in Sickness" by H. Roberts (Dent).

Fig. 73. The air passages. Each bronchus divides and sub-divides many times forming little tubes called broncheoles. At the end of the broncheoles are the air sacs each of which has a diameter of about one-fiftieth of an inch.

The exchange of gases.

In the lungs, carbon dioxide and water vapour pass from the blood through the capillary walls into the sacs, whence they enter the air; oxygen enters the blood.

In the bird, connected with the lungs are numerous thin-walled sacs which lie among the internal organs and extend into some of the bones. These cells act as air chambers, for during inhalation, air rushes through them, and during exhalation, air is forced from them through the lungs. Thus during one complete act of respiration, the blood has a double opportunity of obtaining oxygen from the air.



From "Man and the Nature of his Biological World" by Jean, Harrah, Herman and Powers (Ginn.)

Fig. 74. A small portion of a lung (greatly enlarged) showing the air sacs.

PROBLEM IV: How do insects obtain air?

How the grasshopper breathes.

Air is drawn through the breathing pores (Fig. 75) of which there are several pairs situated in the abdomen and two pairs in the thick muscular thorax or chest region. Waste gases pass out through the pores into the air. The grasshopper has a multiple system of 'intakes' and 'exhausts'.

The process of respiration of a grasshopper is typical of all insects. The air is distributed all over the body in an elaborate system of much-branched tubes called tracheae.

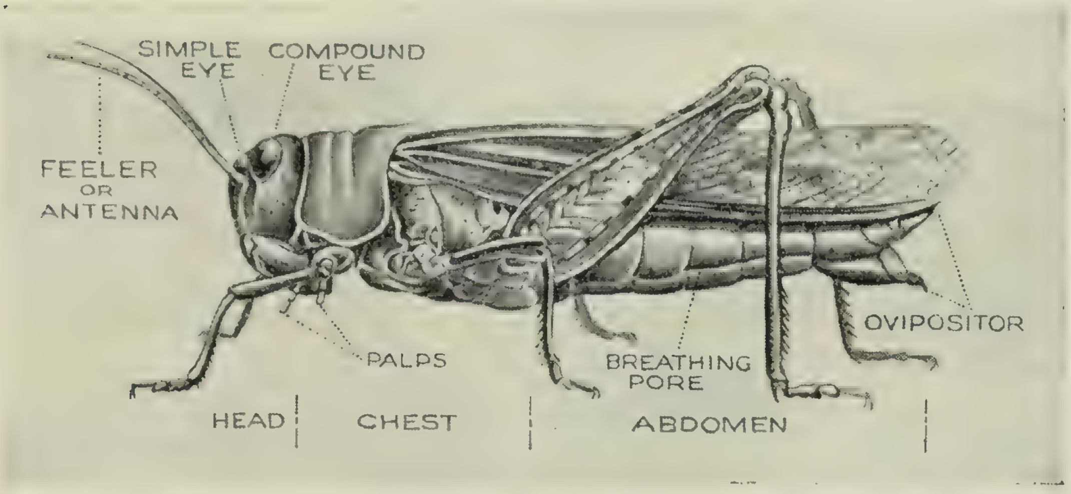


Fig. 75. An adult locust. Notice the long powerful legs used in jumping.

These tubes follow the course of the blood vessels and oxygen enters the blood in every part of the body. The blood passes the oxygen on to the cells.

PROBLEM V: How do fish obtain air?

Anyone who has ever carried fish on a string must have noticed the gills. They consist of comb-like structures of delicate membranes on bony arches. These take the place of lungs and are used in obtaining oxygen dissolved in the water. Water enters the mouth, bathes the gills, and passes out again. Oxygen from the water passes into the blood and carbon dioxide moves in the reverse direc-

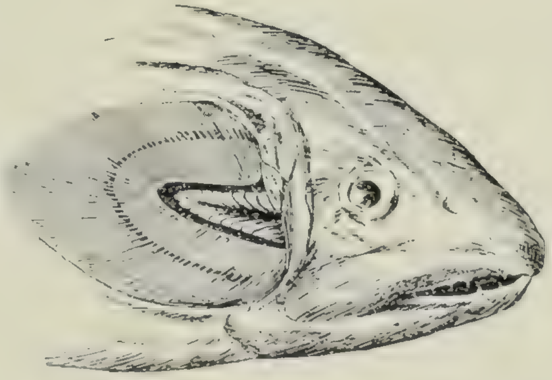


Fig. 76. The gills of a fish.

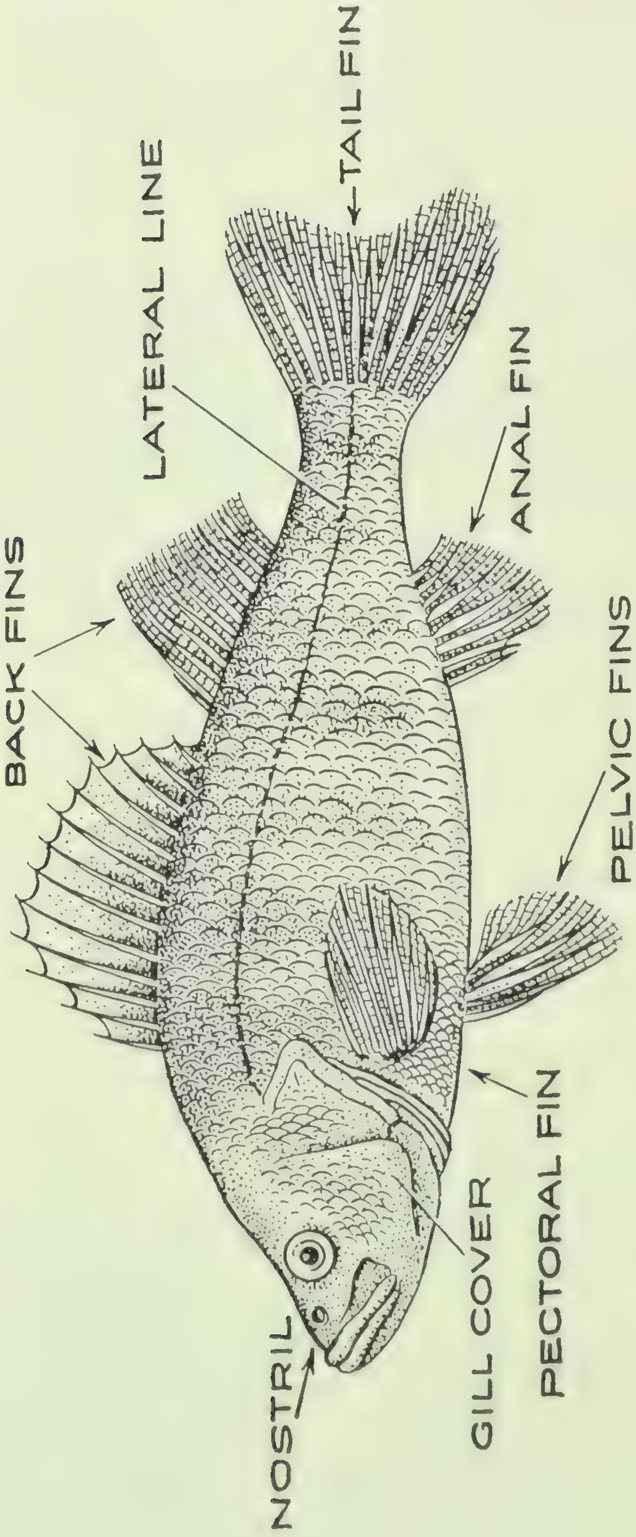


Fig. 77. The perch. How is this animal fitted for its environment?

tion. Suggest a reason for the colour of the gill. Taking into account the space occupied, have the gills a large or small absorbing surface? Of what advantage is a large surface?

C. MINOR STUDY: Fresh air is necessary in our homes.

PROBLEM I: How may homes be properly ventilated?

Convection in gases.

We are all familiar with the inrush of cold air when a door leading to the outside is opened during cold weather, and most people, the unobservant as well as the observant, have noticed which part of their body is affected first. The following experiments will assist us in understanding the currents of air.

Some experiments in which air currents are studied.

(Paper suitable for the second and third experiments suggested below may be made by the following procedure. Soak blotting paper in a solution of potassium nitrate. Allow the paper to dry and then cut it into strips of convenient size.)

(i) Cut a circular piece of light cardboard or paper so as to form a spiral. By means of mucilage, attach to the top of a small thimble that part of the spiral which formerly was innermost in the circle. Support the thimble on the point of a nail fastened to the end of a wooden rod or a piece of glass tubing. The thimble should be free to rotate on the nail. Hold the rod (with the thimble and spiral strip) over a hot stove or radiator. Is there any evidence that the air is in motion?

(ii) Set up the apparatus sketched in Fig. 78. Discover and account for the direction of air currents. Try the effect of temporarily closing one-half of the open end of the chimney.

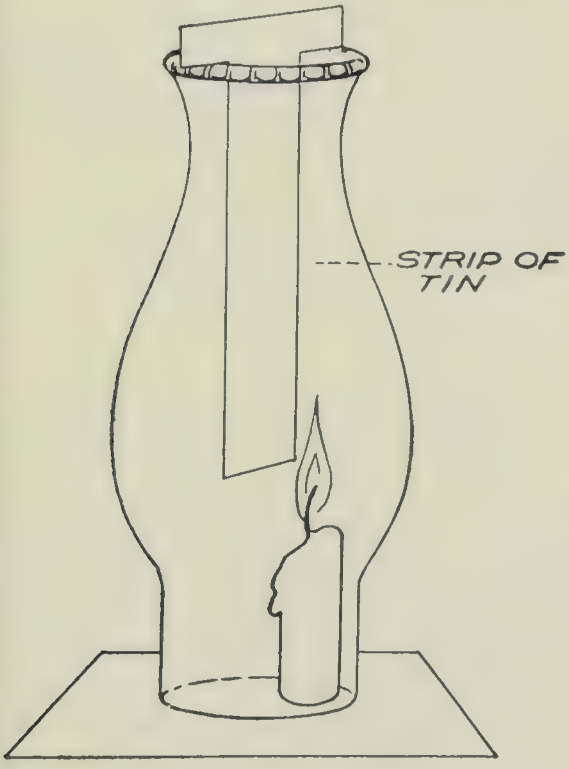


Fig. 78.

(iii) The metal box (Fig. 79) has a sliding glass front and two chimneys. A lighted candle is placed underneath one chimney and smoking paper is held above each of the chimneys in turn.

Are there any currents of air in the chimneys? If there are, is the direction of the current the same in both?

Place the lighted candle under the second chimney. If there is any movement of the air, determine its direction.

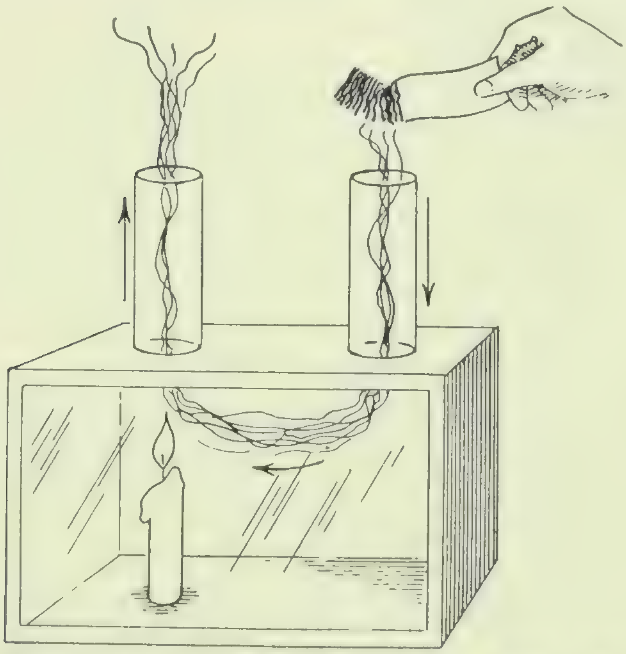


Fig. 79. Why does the smoke take the path indicated?

Since air expands when heated, a cubic foot of cold air is heavier than the same volume of hot air. Consequently, when cold and hot air are mixed, the former pushes the latter upward. The air immediately above the candle became heated and, as a result, it expanded. Colder and heavier air gained admittance from outside and pushed this air up; the process was continuous and so a current was established.

This is an example of how *convection currents* may be established in any gas.

The hot air furnace.

The pupil should examine a hot air furnace and obtain particulars concerning its construction from the local hardware merchants and from the manufacturer.

Does the hot air which enters our rooms come directly from the fire box? From what part of the furnace does it come? Does air enter the furnace to take the place of that which is leaving? If it does, through what pipe does it pass? Why do some pipes enter the furnace near the floor and others close to the top? Give an explanation of the continuous movement of the air through these pipes when the fire is burning. What provision is made for adding water vapour to the hot air? Of what importance is this vapour in the air of the house?

Little difficulty in explaining the action of a hot air furnace will be experienced by a pupil who understands the formation of convection currents.

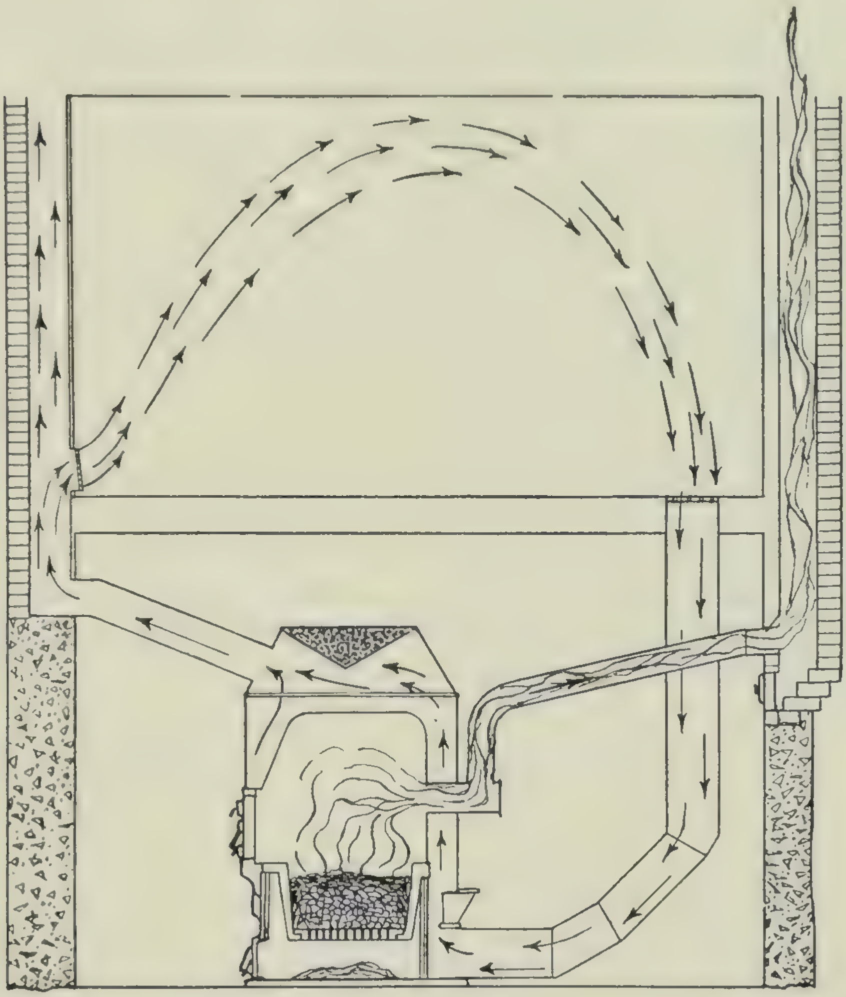


Fig. 80. A hot air furnace.

This type of furnace is a very suitable one for houses of ordinary size. It is comparatively inexpensive to install, the amount of heated air is easily increased or decreased in accordance with the temperature out of doors, a good circulation of air is produced in the house, there is provision for moistening the air, and there is little interference with the placing of furniture in the rooms. On the other hand, it is not always easy to secure an even heat in the house, and at times there may be a leakage of coal gas.

Ventilation.

During each twenty-four hours the average person inhales about 2,600 gallons of air and deprives it of about a quarter of its oxygen. Formerly it was thought that the accumulation of carbon dioxide was responsible for the discomfort and fatigue experienced in crowded ill-ventilated rooms. To-day they are attributed to (a) the lack of motion of the air, (b) a temperature in excess of 70° F., (c) the large amount of moisture which is derived from breath and (d) the existence of unpleasant odours.

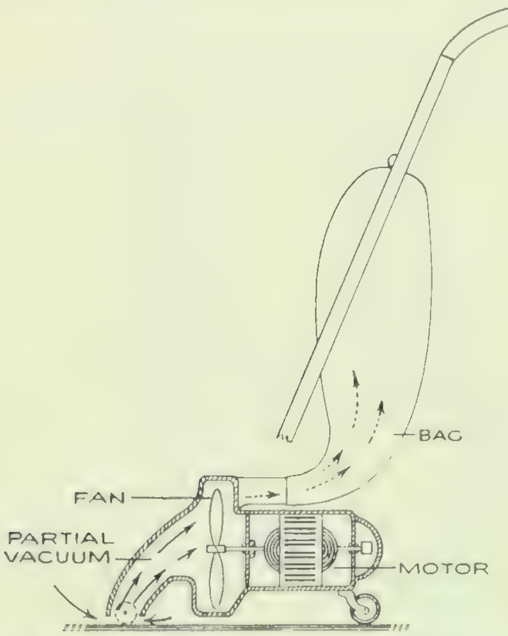


Fig. 81. The vacuum cleaner: A device which makes use of moving air.

PROBLEM I: (a) What air currents exist in a heated room?

Close the doors in a heated room which lacks a ventilation system. Open a window a little at the top and also at the bottom. By means of smouldering touch paper find the direction of the air currents.

Where does the hottest air accumulate in a closed room? Why? Account for the air currents at the opened window.

By opening a window at the top and bottom it is possible to obtain excellent ventilation. To prevent a draught, it is advisable to place a strip of board or glass at the lower opening in such a position that the air entering will be deflected upward.

The draught in a chimney.

From his knowledge of convection currents the pupil will be able to explain the cause of the upward current in a chimney when a fire is burning. Since there is a constant movement of air out of the house, there must be a compensating amount entering. Hence, a fire, especially one in an open grate, is a splendid help towards ventilation.

PROBLEM I: (b) What movement of air is found in a refrigerator?

Why is ice placed at the top of a refrigerator rather than at the bottom? Make a sketch of a refrigerator and indicate the directions of the currents of air.

PROBLEM I: (c) How is an incubator ventilated

In a small incubator find the holes provided for ventilation. Where are they situated? Through which one is it likely that cool air will enter? When the incubator is in operation trace the air currents by means of smouldering paper.

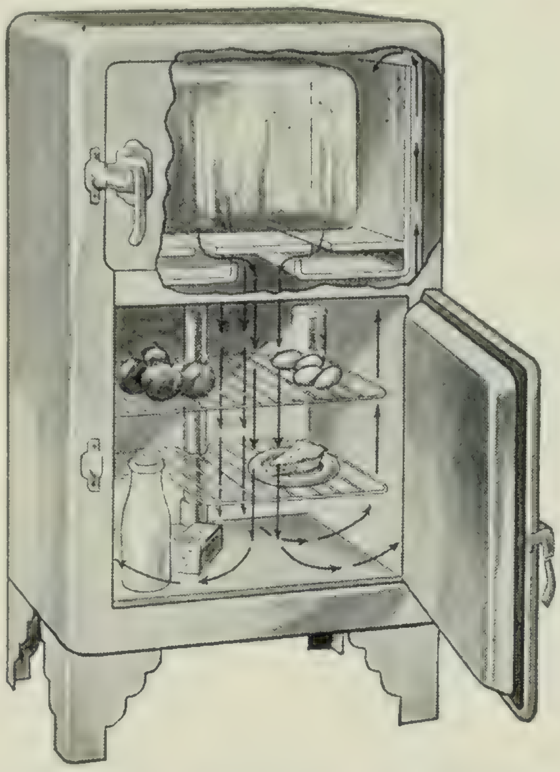


Fig. 82. A household refrigerator. Account for the movement of the air.

Exercises:

1. In 1783 the Montgolfier brothers made a balloon which was filled with hot air. Explain why this balloon was able to ascend. When would it begin to descend?
2. Give a reason for the difference in position of the radiators in a house and the pipes in a cold storage room.
3. Explain why a fire in an open grate is an excellent means of ventilating a room but a poor one for heating it.
4. Without using forced circulation, could a room be heated by a hot air furnace situated at a higher level?
5. Explain why ventilation is more effective if a window be opened at the top, rather than at the bottom.
6. What system of ventilation is used in your school?

ENRICHMENT SECTION, NUMBER 5.

Air conditioning.

Air conditioning is the process by which air is heated, cleaned, and circulated in winter; cooled, cleansed, and circulated in summer. Correct moisture content is maintained during both winter and summer.

There are thousands of dust particles in every cubic foot of air. Over a large city it is estimated that there is about a ton and a half of dust per cubic mile of air.

Air is drawn in from outside the building and filtered. Moisture is taken out by passing the air over coils containing chemicals, or put in by passing it through a spray of water. After it is heated or cooled, it is blown into the rooms by means of an electrically driven fan. The filter removes dust, bacteria, pollen, and other floating particles.

Air conditioning does away with drafts from windows as these are sealed as a part of the process. Since the proper amount of water vapour in the air is maintained, health conditions are more favourable, and furniture lasts longer.

Exercises:

1. The next time you ride on a train, note how the coach is air conditioned. Try to open a window. Observe the workmen adding ice to a compartment under the car. Note the hissing noise as air is driven into the coach.
2. Make a list of the public buildings in your locality that are air conditioned.
3. Secure pamphlets on air conditioning and prepare a report on its operation for your class.

D. MINOR STUDY: Air is playing an important part in modern transportation.

PROBLEM I: What are some of the outstanding achievements in air transportation?

The discovery of crude oil in the Northwest Territories at Fort Norman in 1921 provided the impetus that brought commercial aviation into being in that section of northern Canada. In 1926, gold was found at Red Lake. In the same year, Western Canada Airways was founded and 725,000 lbs. of freight was carried. By 1937, the annual freight carried had reached twenty-five million pounds; three and a half times as much as was carried by the planes of the United States. Articles carried include dogs, dynamite, fuel oil, machinery, baled furs, and supplies of food and clothing.

Fast passenger planes bring civilization to the remote north. Besides carrying mail and express, thousands of passengers have travelled by air. These include miners, prospectors, police, nuns, priests, missionaries and fur trappers. In 1937, Lord Tweedsmuir used this mode of travel to visit Canada's vast northland. 'Mercy flights' into otherwise inaccessible camps and settlements have saved scores of lives.

With the establishment of the Trans-Canada Air Lines in 1938, Montreal is brought by air but 18 hours from Vancouver. These ships carry mail, express, and passengers, but the near future may see freight of the less bulky type carried.

The Imperial Airways literally span the world. Information about this going concern is published monthly in *Imperial Airways Gazette,* Imperial Airways, Ltd., Airway Terminus, London, S.W.I.

A most notable flight was recorded on July 21, 1938. The *Mercury,* a large commercial flying ship, flew non-stop from Foynes in Ireland to Montreal, a distance of 2,930 miles in 20 hours, 20 minutes, or, at an average speed of 140 miles per hour. It flew from the back of a seaplane, double its size and with twice its horse-power. The object of the 'pick-a-back' system is to do away with the strain of rising to a safe flying level by a heavily loaded plane. The *Mercury* created three records:

1. The first commercial flight across the North Atlantic by a 'heavier-than-air' machine.
2. The first east to west crossing from the British Isles to Montreal.
3. The fastest time for the east to west crossing of the North Atlantic.

Exercises:

1. Watch your newspaper for flying activities in Canada's northland. Cut out such articles and paste them in your scrapbook.
2. Ask your teacher to explain to you how balloons are able to stay up in the air.

3. Will dirigible balloons replace aeroplanes for northern transportation of mail, express, freight and passengers? What difficulties lie in the way of such an air service?
4. Explain the difference between 'lighter-than-air' machines, and 'heavier-than-air' machines.
5. Inquire for rates on mail, express, and passenger service on the Trans-Canada Air Lines.

UNIT 4. MAJOR STUDY: Man has learned to control fire and make it work for him.

We shall never know who made the first fire. Perhaps it was by accident, or man may have noticed that heat or even fire was produced when the wind made the dead branches of trees to rub against each other. We do know that civilization began around a fire.

Without fire, the peoples of the earth would still be wandering tribes. Fire cooks our food, gives us the great iron and steel works of to-day, makes possible our pottery, gives us steam power, and heats our homes. By his ability to control fire, man has been able to dominate the physical world.

Exercises:

1. Name several things which the absence of fire would take from our present day civilization.
2. Look up the myth of Prometheus in an encyclopedia and learn how this old Greek story accounts for the origin of fire, how it was stolen from heaven and given as a priceless gift to men.
3. Show how man's ability to control fire has enabled him to inhabit otherwise uninhabitable places on the earth.
4. Ordeal by fire was part of English law during mediaeval times. Look up this topic in some history of England.
5. What is the derivation of the word 'curfew'? Read about the origin of this word in the time of William the Conqueror.

A. MINOR STUDY: Fire is useful as well as destructive.

PROBLEM I: Why did primitive man worship fire?

Primitive man must have been filled with feelings of the greatest terror when he looked upon lightning or active volcanoes. These, he felt, were the acts of gods endowed with awe-inspiring power. We have plenty of evidence that ancient man regarded fire with utmost reverence. In the Bible we read of the story of the pillar of fire in the wilderness, of Elijah's chariot of fire, of the burning fiery furnace, of the burning bush from which God spoke to Moses; all show that fire has ever been a symbol of power and mystery. Five hundred years before Christ there were fire-worshippers in Persia. There were, and still are, fire-worshippers. In the Acropolis at Athens a sacred lamp burned continuously and in Rome the vestal virgins were guardians of a holy fire. Even to-day we regard the torch as a symbol of high ideals.

PROBLEM II: What has science contributed to our knowledge of fire making?

An effect of rubbing substances together.

Rub a coin or other piece of metal vigorously to and fro on a board. How is this metal affected? What happens to your hands if you are not careful when sliding down a pole or rope? Give other examples of the production of heat by *friction*.

An effect of striking two bodies together.

Feel a piece of lead and then strike it repeatedly with a hammer. What difference, if any, has the hammer made in the heat of the lead? Has the head of the hammer been affected? Recall other examples you have observed of the production of heat by *percussion*.

How has fire-making progressed?

The earliest method of obtaining fire was by rubbing sticks

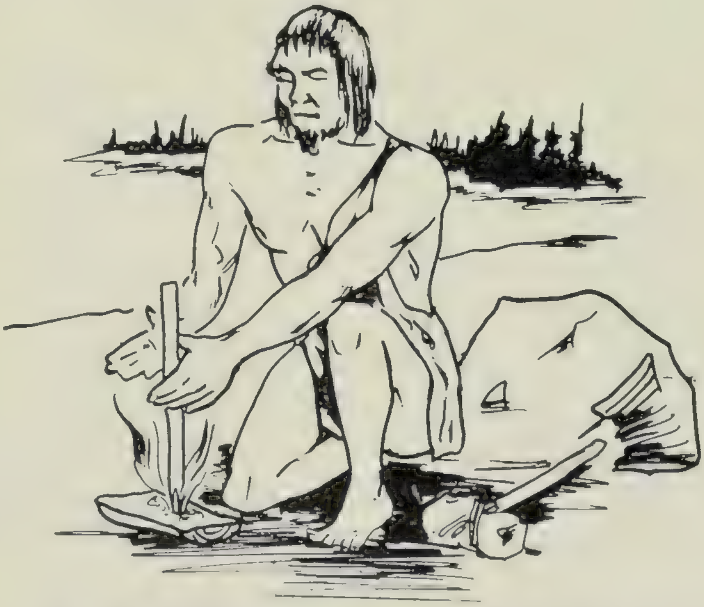


Fig. 83. This method of fire-making has been used thousands of years. Do you know what made the sticks burn?

together. At first this was done by hand, but later some ingenious people found that a bowstring could be used. By means of this early machine, a stick with one end touching a piece of wood, was made to rotate. Everyone has observed that sparks are produced when two hard stones are struck together. This led to the production of fire by striking flint against steel. The spark ignited tinder consisting of dried moss, rotted wood or other easily kindled material contained in a tinder-box. In the flintlock musket, the powder was ignited by a spark produced by the striking of flint against steel and the device is still used in cigar-lighters and gas-lighters.

In 1827 the match was invented in England. So accustomed have we become to the use of this object that a proper appreciation of it can be gained only by reflecting on the means of producing fire before its invention.

Ignition of a match.

The wood of the modern match is soaked in a chemical to prevent it from smouldering after the flame is put out. Then the upper part of the wood is dipped in melted paraffin. This may be seen if a burning match is observed closely. The head contains phosphorus, a substance which is ignited easily, and certain other chemicals which burn readily. When the match is 'struck', the heat produced by friction causes the phosphorus to take fire. This kindles the other substances in the head. These, in turn, set fire to the paraffin, and finally the wood burns. In the manufacture of safety matches, the phosphorus is omitted from the head and placed on the striking surface.

In the lighting of a match we have a good example of the ease or difficulty with which different substances are kindled. We may think of the easily kindled phosphorus which was ignited by friction as the lowest rung on a ladder, and the sliver of wood as the highest. It would have been difficult, if not impossible, to mount at once from the lowest to the highest step. The ascent is made easy by the presence of the intermediate rungs.

B. MINOR STUDY: Heat is obtained from the combustion of fuels.

PROBLEM I: What conditions are necessary for combustion?

Exercises:

1. Light a small candle and place over it a drinking glass. Describe what happens. Remove the glass and light the candle again. Cover the candle again and, when the flame is on the point of being extinguished, lift the glass quickly. Will a candle continue to burn if deprived of air?
2. Describe how to adjust the draughts on a stove or furnace (a) when you wish the fire to burn brightly, (b) when you desire less heat, (c) when you wish to bank the fire for the night. How do these adjustments enable you to achieve your object?

How to light a fire

Ashes are removed from the grates and, in order that air may enter, the draughts are arranged in accordance with the instructions of the manufacturer of the stove or furnace. A plentiful supply of crumpled paper is placed on the grate and wood shavings or very small sticks are laid lightly on top. Then, larger and larger sticks are added, care being taken to place them so that they cross. A lighted match is applied to the paper, and a small amount of coal is placed on the fire when the larger pieces of wood begin to burn. After the fire gains in vigour, more coal is added. Coal-oil or gasoline should *never* be used in lighting fires.

During this operation, we first climbed the small 'fire ladder' of the match. Then the readily ignited paper was kindled. This set fire to the shavings which, in turn, heated the sticks until they burst into flame. When a considerable amount of heat was produced, the coal finally began to burn.

Briefly, the three essentials for combustion are:

1. A substance that will burn.
2. A supply of oxygen.
3. A kindling temperature.

[NOTE: Place a piece of wood in an oven and raise the temperature until the wood bursts into flame. The temperature at which this occurs is the kindling temperature of the wood.]

Exercises:

1. Why does a brisk wind make a bon-fire burn brightly?
2. What happens when a candle burns? Explain the three cones of flame.
3. Why do we find glowing coals buried among the ashes of a fire?
4. What is the function of a wick in a candle or lamp?
5. Describe the construction of the burner of a coal-oil lamp.

PROBLEM II: What are the products of combustion?

Demonstration of the presence of carbon in fuels.

(i) Hold a burning splint in a jar of air. Test with limewater the gas which remains. Is carbon dioxide present? What was the source of the carbon? How could you show that it was not presesnt to the same extent in the original air? How did the tree obtain the carbon?

(ii) Demonstrate the production of carbon dioxide when a candle burns.

(iii) If your school is supplied with gas, show that carbon dioxide is one of the products of combustion.

(iv) Devise an experiment to prove that coal or peat contains carbon.

We have taken advantage of the formation of carbon dioxide during combustion in order to demonstrate the existence of carbon in fuels. Water is a substance formed by the union of hydrogen and oxygen gases. Hence, if we could show that water is produced when a fuel burns, we would have evidence that hydrogen was present in that fuel.

Demonstration of the presence of hydrogen in certain fuels.

(i) Hold a flask containing ice-cold water above the flame of a Bunsen burner or an alcohol lamp. Has moisture condensed on the cold surface? How would you show that this was really water? How would you demonstrate that much or all of this moisture resulted from the combustion, and not from the condensation of water vapour originally present in the air?

(ii) Show that water vapour is formed during the burning of wood, and of a candle.

(iii) Recall the dripping of water from the cold exhaust pipes of automobiles. What is the inference? (Sufficient water vapour to give a gallon of water, if condensed, is formed when a gallon of gasoline burns.)

When coal, peat, wood, kerosene and gasoline are burned, the carbon present becomes oxidized to carbon dioxide, and the hydrogen to hydrogen oxide. The latter is a chemical name for water.

PROBLEM III: Do we get heat from sources other than fuels?

We have observed that the heat for our cooking and for heating our homes comes from the burning of fuel. We have already described the nature of fuel. This is called a chemical source of heat because the fuel is changed chemically when it is burned. When no new substance results from the change, it is a physical change.

If you sit in the sun, you will feel warmer than if you sit in a shady spot. The sun is our greatest source of heat. Our winters are colder than our summers because the sun's rays are spread over a greater area. This is due to the fact that the tipping of the earth's axis gives greater slant to the rays.

Heat produced when a gas is compressed.

Feel the barrel of a bicycle pump and then pump air rapidly into an inner tube or football bladder. Has the barrel become heated? Is there any friction between the piston and the cylinder? Suggest a possible cause for at least some of the heat.

It is true that some of the heat produced in the pump is the result of friction, but there is another source. When air and other gases are compressed, heat is developed. (The opposite happens when a gas is allowed to expand. Air permitted to escape through the valve of an automobile tube is slightly cooler than that inside.)

The electric current is used in our homes to produce heat. We have electric stoves, toasters, coffee percolators, and curling-tongs. Examine the heating element in an electric toaster.

In brief, the chief sources of heat are the sun, chemical change, the electric current, friction, percussion, and compression.

C. MINOR STUDY: Man has learned how to control fire.

PROBLEM I: Has fire caused great losses?

Every year fire causes the painful death of many human beings and animals, and reduces to waste millions of dollars worth of property. In 1666, fire destroyed London. A recent motion picture "In Old Chicago" depicted the burning of that city, while the picture "San Francisco" showed the destruction by fire of that city following an earthquake.

From the *Canada Year Book, 1938,* we learn that to-day 60% of the original forest has been burned, about 14% has been cut, and about 25% remains. The average area burned over each year for the ten-year period 1926-1935 was slightly over 2,000,000 acres with an annual total loss of $4,500,000 to property.

Some large Canadian fires during this century were:

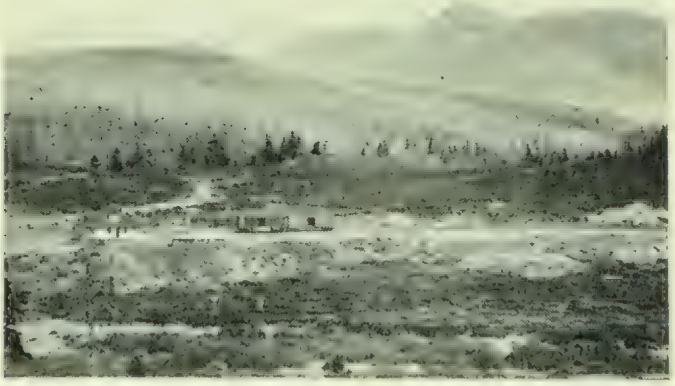


Fig. 84. Destruction of timber by a forest fire.

1. 1908. Fire, originating in the forests around Fernie, B.C., destroyed that city.
2. 1911. The mining camp of Porcupine was destroyed with a loss of 72 lives and property damage of $3,000,000.
3. 1916. The same general region was burned over with a loss of 224 lives.
4. 1922. Fire destroyed the town of Haileybury and other centres.
5. November 19th, 1936. One of the most destructive prairie fires in Alberta's history roared out of the Bow forest reserve and burned over 100,000 acres of hay land, wiping out the homes of five ranchers and scattering livestock over a wide area in the Cochrane-Jumping Pound District.

PROBLEM II: Can fires be prevented?

Fires may be prevented if we understand how they are caused.

1. Carelessness in the use or storage of combustible materials.
   - (a) Leaving matches where children may find them.
   - (b) Cleaning clothes with benzene, naphtha, or gasoline.
   - (c) Cleaning floors with gasoline.
   - (d) Starting a fire with coal-oil.
   - (e) Leaving uncovered gasoline or coal-oil near a flame.

   - (f) Leaving a lamp in an unsafe place.
   - (g) Seeking leakages of gas with the aid of a lighted match.
2. Hazards in connection with chimneys and improperly installed stoves or furnaces.
   - (a) Having joists supported by a brick chimney.
   - (b) Allowing soot to accumulate in a chimney.
   - (c) Placing stoves on rugs or wood.
   - (d) Having stove or furnace pipes close to partitions, joists, or other wooden structures.
3. Hazards arising from defective electric wiring.

   Fires are often caused by improper insulation of wires carrying electric current.
4. Carelessness in the disposal of waste.
   - (a) Putting hot ashes in a wooden or cardboard box.
   - (b) Dumping hot ashes in an unsafe place.
   - (c) Permitting the accumulation of oily rags or other waste in which spontaneous combustion may occur.
5. Fires caused by smokers.
   - (a) Careless disposal of lighted matches and cigarette ends.
   - (b) Smoking in bed.

PROBLEM III: What have we learned about fire fighting?

We learned that there are two ways to control fire:

1. Shutting off the supply of oxygen.
2. Reducing the temperature below the kindling point.

In a previous section, we discussed the use of water for both of these purposes. If the clothes of a person catch fire, one should not allow him to run around, but should make him lie on the floor and exclude the air from the flames by wrapping a rug, blanket, or overcoat around him.

In fighting a prairie fire it is common practice to plough a fire guard across the path of the approaching fire. Back-firing is also practised. This consists of starting a fire, that is kept under control, in the path of the approaching fire, thus leaving a "burned-off" strip of land over which the main fire cannot pass. Sacks soaked in water are used to beat out the flame.

A portable gasoline water pump that weighs from 45 to 100 pounds is the most recent equipment added to forest preservation. This pump will deliver efficient water pressure as far as 7,000 feet from a water supply, and can also be used in relays for much greater distances.

Fire-extinguishers contain baking soda solution and an acid. When the extinguisher is inverted, these are brought together and great quantities of carbon dioxide are produced. The pressure of the gas causes the solution to be forced violently out of the tube. Not only does the liquid help in putting out the fire, but also the carbon dioxide assists. Being heavier than air, it excludes oxygen from the burning substance just as a blanket would.

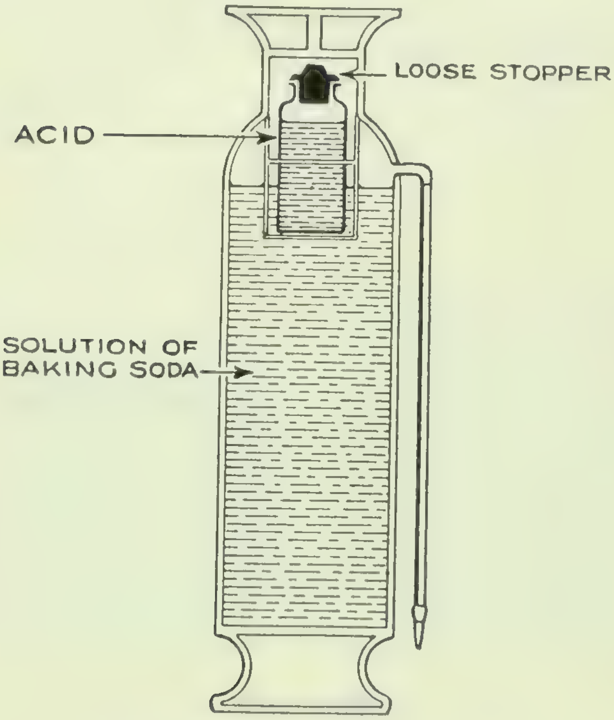


Fig. 85. A fire-extinguisher.

Exercises:

1. Sand is sometimes used to extinguish fires. Explain why it serves this purpose.
2. Give examples drawn from your reading or experience of fires caused by the methods listed. Suggest other fire hazards.
3. For what purpose is asbestos used? Where is this substance mined in Canada?
4. How are you protected against faulty electric wiring?
5. Sum up in one word the chief causes of destructive fires.
6. Why is it wise to wrap a coat or rug tightly around a person whose clothes have caught fire?
7. A match burning on the ground is extinguished when you stamp on it. Give an explanation.
8. Why may bellows be used to make a fire burn more brightly?

UNIT 5. MAJOR STUDY: Weather conditions are the result of definite causes.

The science of weather is called "meteorology", from the Greek word *meteoron,* meaning "things in the air." Men who study weather scientifically are called "meteorologists".

A. MINOR STUDY: Weather signs are observations made in order to foretell changes in the weather

PROBLEM I: Why do people want to foretell the weather?

Man has always been anxious to predict the weather. Primitive man was dependent on weather conditions for hunting, fishing, and fighting. Weather prediction plays a very important part in living in this modern age. Warnings given of coming storms benefit seamen, aviators, travellers, and others. Warnings given of freezing weather benefit farmers, fruit growers and shippers. In the country to the south of us, the public is put upon its guard against cyclones, tornadoes and floods.

The weather-wise have credited the stars, the moon, the habits of animals, the appearance of the sky at sundown, with holding the secret of the weather. Some of the weather lore is but fancy, some is superstition. The aviator, however, has learned to forecast the weather from the ground by the shape, colour and density of the clouds.

PROBLEM I (a): What weather sayings do you know? Are they dependable?

The Indians will tell you that if you see a ring around the moon rain will surely follow. Dad's rheumatism or pet corn gives him warning of a change in the weather. The following bits of "weather wisdom" are found in our literature:

"Rainbow in the morning is the sailor's warning;
Rainbow at night is the sailor's delight."

"Evening red and morning gray,
Will set the traveller on his way;

Evening gray and morning red
Will bring down rain upon his head."

"There will be good weather when the cat washes herself, but bad when she licks her coat against the grain, washes her face over her ears, or sits with her tail to the fire."

"When flies bite greedily, expect rain."
"A bee was never caught in a shower."
"If the cock goes crowing to bed, he'll certainly rise with a watery head."
"When smoke drops a pall, the rain will soon fall."

Exercises:

1. Read Matthew XVI: 2, 3; Luke XII: 54-55.
2. State any other "Weather wisdom" that you have heard.
3. Search out the cause for the colours of the rising and setting sun.
4. Why do the sun and moon appear so large near the horizon?
5. What is the true explanation of the rainbow?

PROBLEM II: Has man ever attempted to encourage nature to produce rain?

In certain parts of the world, natives attempt to woo rain by imitating the sounds and fancied movements of storms. Some even make foamy liquid mixtures as a hint to the clouds to drop their moisture. The Burmese make figures of men and women and throw them along with pagodas into the rivers, in the hope that Nature will deluge the land in imitation. At the time of Napoleon, France still wooed the rain in a manner similar to this.

Fiddletown, California, about ninety years ago derived its name from the fact that fiddles were played there by the colonists in the belief that by so doing they could induce rain to fall.

Modern scientists have attempted to bombard the clouds with guns or, as in the Hatfield experiments in Alberta, by scattering chemicals from the air. To date, little or no success has been achieved.

B. MINOR STUDY: The weather is made up of various conditions of the atmosphere.

PROBLEM I: What factors make up our weather?

When we observe the conditions of the atmosphere from day to day and note such factors as temperature, air pressure, wind, humidity, precipitation, clearness or cloudiness of the sky, we are studying weather.

PROBLEM II: What instruments are used in studying weather?

The thermometer is the most useful instrument for keeping track of the weather. Its name comes from two Greek words meaning "to measure hotness".

We have noted the effect of heat on certain substances. While the change in size is of very considerable importance in every day affairs, we shall confine ourselves to a use made of it in the case of two liquids. One of these is mercury, a substance of interest because it is the only metal which exists in the liquid state under ordinary conditions; the other is alcohol. First of all, let us make sure that these liquids do expand when heated and contract when cooled.

PROBLEM II (a): Is the volume of mercury affected by heating?

Examine a mercury thermometer. Warm the mercury with the hand. Is its volume affected? Notice the level of the mercury and then hold the bulb under a cold water tap. Look at the mercury level again. Does mercury expand when heated and contract when cooled?

PROBLEM II (b): Is the volume of alcohol affected by heating?

Repeat on an alcohol thermometer the observations made above. To what conclusions do they lead you? (Colouring matter is usually added to make the alcohol more visible.)

Some people are quite expert in estimating by feel how warm or cold a liquid is. You may be interested in testing your own ability.

PROBLEM II (c): How accurate are your estimates of hotness and coldness?

Ask someone to pour equal amounts of cold water into four beakers and then to add hot water in amounts which vary but slightly. You should not be present while this is being done. Then, using your fingers to test the degree of hotness, arrange the beakers in order from coldest to warmest. Place a thermometer in each beaker and note the number to which the mercury rises. How accurate were your estimates?

Our estimates of hotness and coldness are frequently very faulty. If you place your hand in hot, and then in luke-warm water, the latter feels cold; but if you use cold water at first, instead of hot, the tepid liquid feels warm. Because of the need for more accurate information concerning warmth and coldness than our own sensations provide, we make use of the alterations in volume of mercury or alcohol.

Examination of a broken thermometer.

The pupil should examine the stem of a broken thermometer and notice the diameter of the tube through which the liquid passes. Of what advantage is the narrowness of this tube?

PROBLEM II (d): How are the numbers on a thermometer stem obtained?

How does the manufacturer know where to place the different marks or graduations? What is a degree? These are questions which occur to us. Clearly there must be some system, for if we select good thermometers made by different firms and place them in the same liquid, the readings are all the same.

The freezing point of water.

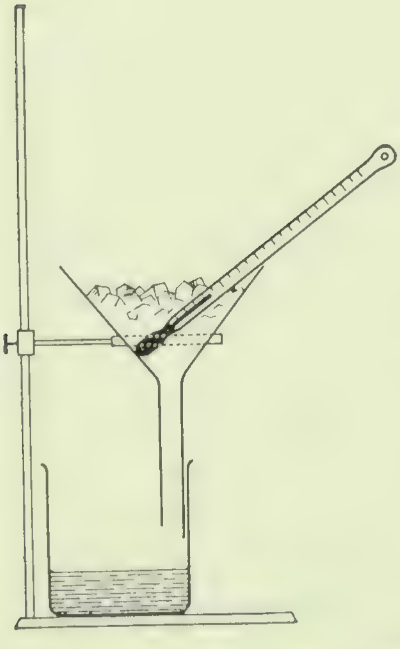


Fig. 86. How to find the freezing point of water.

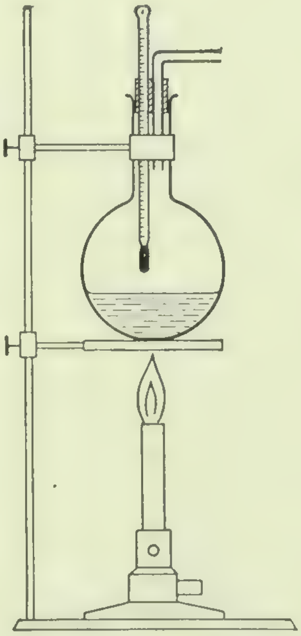


Fig. 87. How to find the boiling point of water.

Place finely powdered ice in a funnel. When the ice begins to melt, insert a thermometer. When the level of the mercury or the alcohol becomes stationary, take the reading. (The freezing point of water and the melting point of ice are the same.)

The boiling point of water.

Set up the apparatus shown in Fig. 87. Here the bulb and as much as possible of the stem are surrounded by the steam from the boiling water. Note the highest point attained by the mercury or alcohol.

(a) *Fahrenheit scale.*

The freezing and boiling points of water are called the fixed points of the thermometer. When an ungraduated thermometer is placed in freezing water, the number 32 is written at the lowest level at which the alcohol or mercury stands. (Once it was thought that the lowest temperature attainable was 32 degrees below the freezing point of water.) Similarly, at the level reached when the thermometer is surrounded by the steam from boiling water at a pressure of exactly one atmosphere the number 212 is marked. The difference between the freezing and boiling points is divided into 180 equal parts; each of these divisions is called a degree (°) Fahrenheit. This scale, devised by Fahrenheit, is seen on the household thermometers of English-speaking peoples.

(b) *Centigrade scale.*

A different scale, the Centigrade, is marked on thermometers employed for scientific purposes. When a Centigrade thermometer is required, 0 is marked at the level of the liquid when the instrument is placed in melting ice (or freezing water). At the level reached when the thermometer is surrounded by steam, at a pressure of exactly one atmosphere, the number 100 is placed. The stem between these two points is divided into 100 equal parts and each is known as a degree (°) Centigrade. In both Fahrenheit and Centigrade thermometers, the graduations are extended above the boiling point and below the freezing point.

Apart from the method of graduation, there is no difference between a Fahrenheit and Centigrade thermometer.

Practice in the use of a thermometer.

(i) Find the temperature of (a) the room, (b) the body, (c) a refrigerator, on both Fahrenheit and Centigrade thermometers.

(ii) Keep a daily record of the Fahrenheit and Centigrade temperatures out of doors. The reading should be made at the same time every day and the thermometers should be placed so that they are in shade at the time chosen.

How to convert readings from one scale to another.

If you have learned how to draw graphs, make one from the pairs of temperature readings you have secured. Use the graph to convert readings from one scale to the other.

In your work in mathematics you have learned to use formulas. You have also learned how to add, subtract and multiply "signed" numbers. Since 100 degrees on the Centigrade scale equal 180 degrees on the Fahrenheit scale, we can compare two readings by ratio:

$$\frac{C}{100} = \frac{F\text{-}32}{180} \quad \text{or} \quad C = \frac{5}{9}(F\text{-}32)$$

If we replace F in the formula by the reading on the Fahrenheit scale, we can find the equivalent reading on the Centigrade scale.

Example:

Find the reading on the Centigrade scale that corresponds to a reading of –40° on the Fahrenheit scale.

Solution:

$$C = \frac{5}{9}(F\text{-}32^\circ) \quad \text{or} \quad C = \frac{5}{9}(-40^\circ\text{-}32^\circ)$$

$$= \frac{5}{9}(-72^\circ)$$

$$= -40^\circ$$

–40° F. and –40° C. are the same temperature.

PROBLEM II (e): Why are two thermometric liquids used?

A thermometer which involves the use of a liquid would burst if the boiling point of that liquid were approached. Mercury, with a boiling point of 675 degrees F. (357 degrees C.), may be used for a much higher temperature than alcohol, which boils at 173 degrees F. (78 degrees C.)

Another point to be borne in mind is the freezing point of the thermometric liquids; once the liquid solidifies, the instrument is useless. Alcohol has the advantage over mercury when low temperatures are being recorded because it does not freeze until –173 degrees F. (114° C.) is reached, whereas mercury solidifies at the much higher temperature –38 degrees F. (–39° C.).

PROBLEM II (f): What instruments are used in recording weather?

We have already learned about the discovery and construction of a mercury barometer. This instrument is used to measure the changes of atmospheric pressure on the earth. Robert Boyle, about 1690, was the one to suggest that the differences in air pressure day by day might bear some relation to the weather. By 1772, enough data had been obtained to verify the assertion and to permit Jean Andre Deluc, a Swiss, to publish a book of rules for predicting the weather by the barometer. A much more compact instrument is the aneroid barometer.

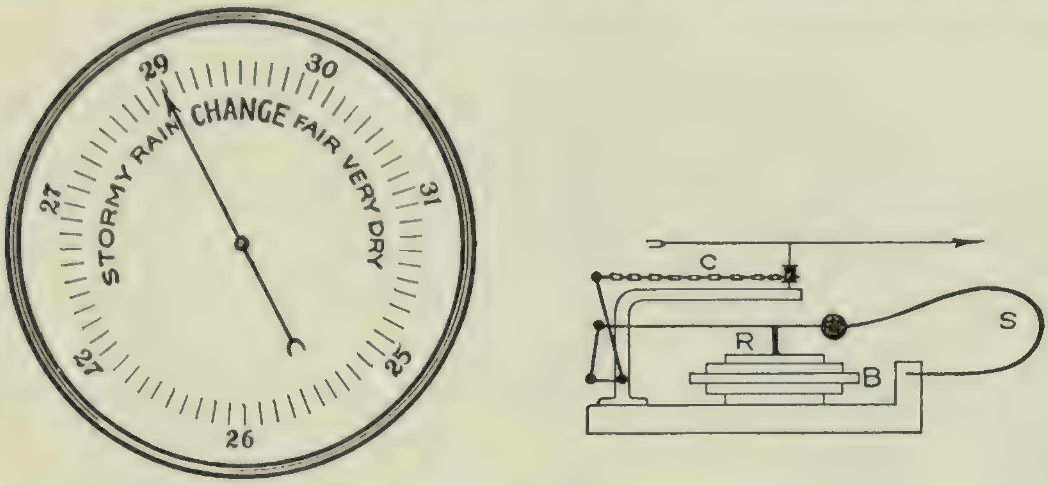


Fig. 88. The aneroid barometer.

B is a box from which most of the air is exhausted. The flexible lid of B presses against a short vertical rod R connected with the spring S. As the atmospheric pressure changes, the motion of the lid is communicated to a system of levers. These multiply the motion and move the chain C. The chain is wound on a spindle connected with the pointer.

The hygrometer is an instrument used to measure humidity. In 1782, De Saussure discovered that a human hair short-

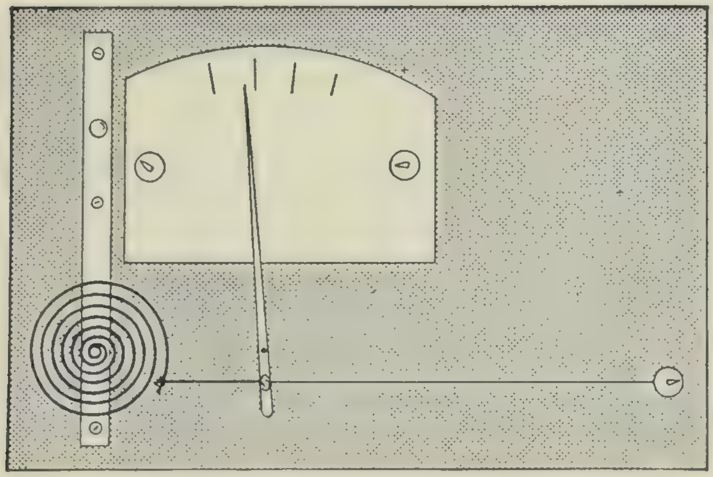


Fig. 89. A home-made hair hygrometer. As the relative humidity increases, the length of the hair increases. When the relative humidity decreases, the hair becomes shorter. The hair should be washed in caustic soda solution in order to remove grease.

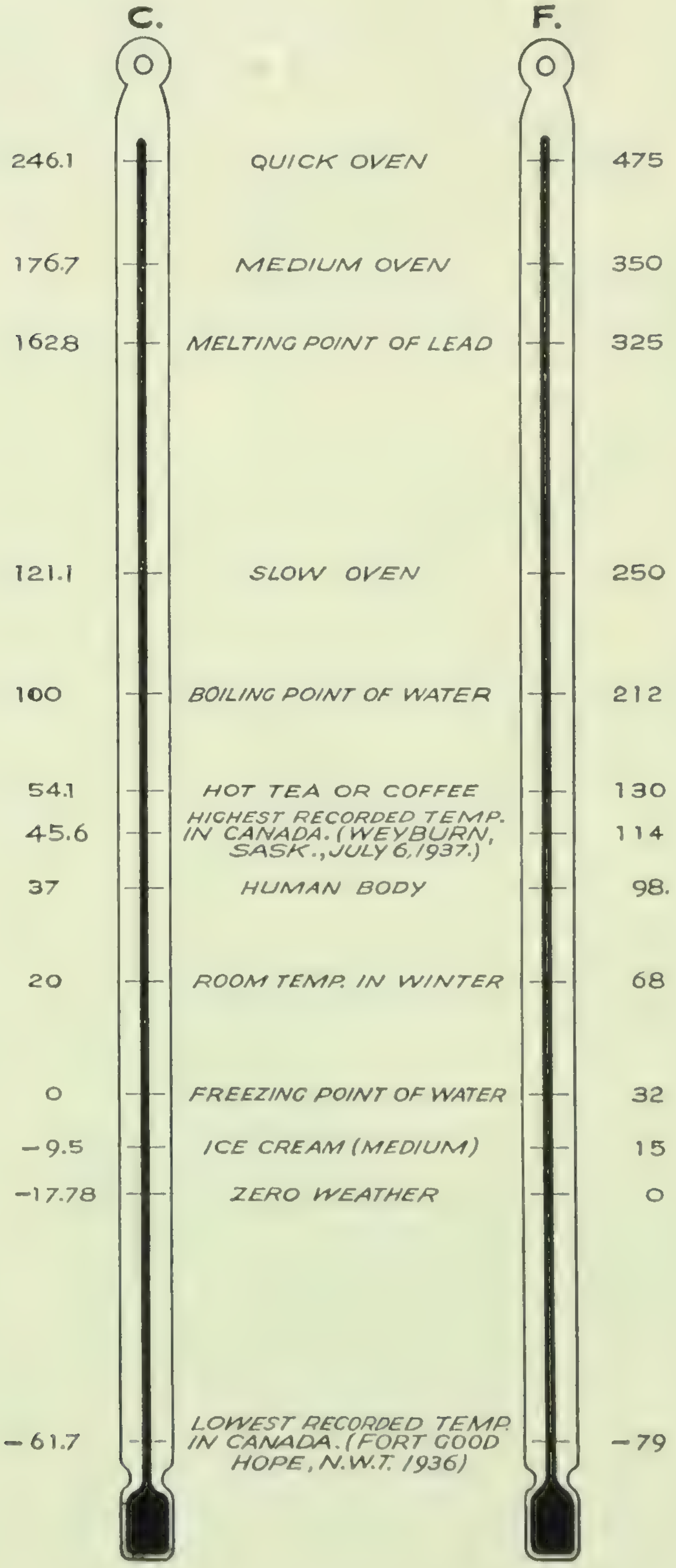

C.
F.
246.1 QUICK OVEN 475
176.7 MEDIUM OVEN 350
162.8 MELTING POINT OF LEAD 325
121.1 SLOW OVEN 250
100 BOILING POINT OF WATER 212
54.1 HOT TEA OR COFFEE 130
45.6 HIGHEST RECORDED TEMP. IN CANADA. (WEYBURN, SASK., JULY 6, 1937.) 114
37 HUMAN BODY 98.
20 ROOM TEMP. IN WINTER 68
0 FREEZING POINT OF WATER 32
−9.5 ICE CREAM (MEDIUM) 15
−17.78 ZERO WEATHER 0
−61.7 LOWEST RECORDED TEMP. IN CANADA. (FORT GOOD HOPE, N.W.T. 1936) −79

Fig. 90 Some interesting temperatures on the Centigrade and Fahrenheit scales.

ened in moist air and lengthened in dry air in a fairly reliable fashion. He attached a pointer to the hair and was able to measure the moisture in the atmosphere.

The wet and dry bulb hygrometer.

It is certain that in future people will pay more attention to the humidity of their houses than they did in the past. To use the wet-and-dry-bulb hygrometer (Gk. *hygros,* wet; *metron,* measure) to determine relative humidity is a simple matter. Two thermometers are hung side by side. Around the bulb of one is tied a piece of linen, an end of which dips into a little vessel of water. The water rises in the cloth and keeps the bulb moist. Evaporation from the linen produces cooling, so that the reading on the wet bulb thermometer is lower than that on the dry. The lower the relative humidity is, the more rapid is the evaporation. The more rapid the evaporation, the more the wet bulb cooled. In short, when the relative humidity is low, there is a greater difference between the readings on the thermometers than when it is high. By referrng to a table which usually accompanies the hygrometer, the relative humidity is quickly found. A part of the table is given below:

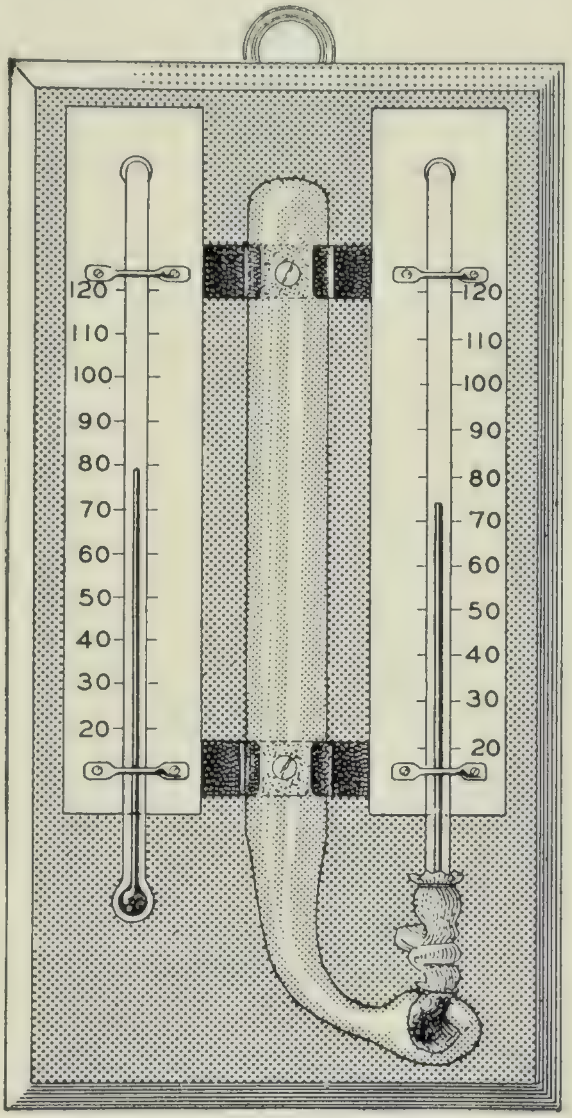


Fig. 91. A wet-and-dry bulb hygrometer is useful in the home. By means of it, one can easily find the relative humidity.

Reading on dry bulb thermometer in Fahrenheit degrees	Difference between the readings on the thermometers in Fahrenheit degrees														
	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	21°	22°
	Relative Humidity														
66°	61	57	53	48	44	40	36	32	29	25	21	17	14	10	
67°	62	58	53	49	45	41	37	33	30	26	22	19	15	12	
68°	62	58	54	50	46	42	38	34	31	27	23	20	16	13	
69°	63	58	55	50	47	42	39	34	32	27	24	20	18	13	
70°	64	59	55	51	48	44	40	36	33	29	25	22	19	15	12
71°	64	60	56	52	48	45	41	37	33	30	27	23	20	17	13
72°	65	61	57	53	49	45	42	38	34	31	28	24	21	18	15

We shall take an example—

Reading on dry bulb thermometer	70° F.
Reading on wet bulb thermometer	56° F.
Difference	14° F.
Relative humidity (from table)	40 per cent.

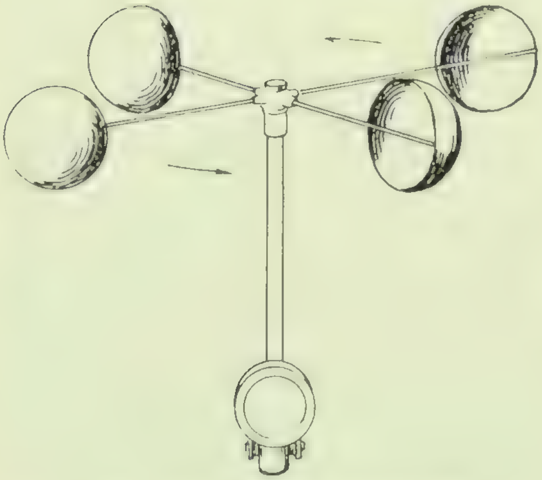


Fig. 92. An anemometer.

The anemometer is an instrument designed to measure the velocity of wind. The first anemometer was a flat swinging tablet devised about 1667 by Sir Christopher Wren. He measured the velocity of the wind by the slant of this tablet. The modern instrument with its cup-like form was invented by Richard Edgeworth early in the nineteenth century. Weather vanes were used to detect the direction of the wind.

The first attempts to measure the depth of rain that fell were made with crude instruments. The modern rain gauge is devised to prevent drops from splashing out of the mouth of the funnel into which they fall. It is a cylinder about two feet long. The area of the funnel top is ten times the cross section of a tube placed under it in which the rain is collected and measured. One inch in the tube represents one-tenth of an inch of actual rainfall. In the self-recording rain gauge, a tiny bucket tips each time a hundredth of an inch of rain has fallen into it, thus making an electrical contact that controls a recording pen.

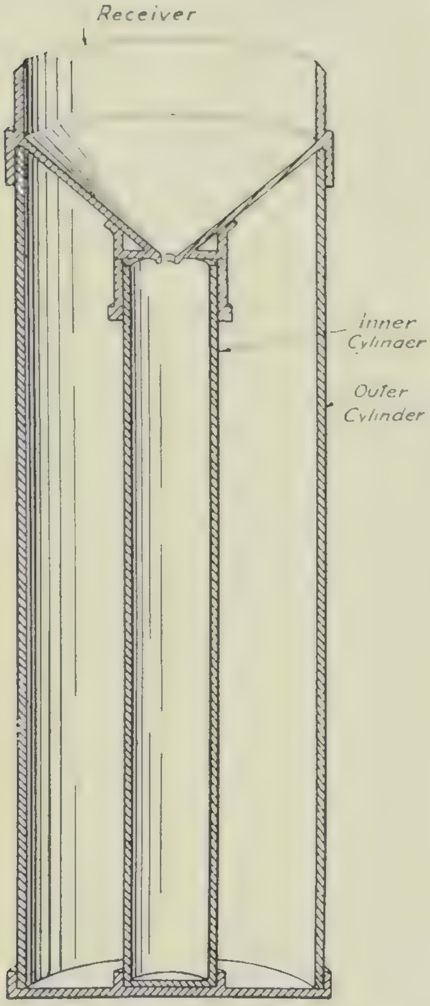


Fig. 93. Rain gauge

PROBLEM III: How is air affected by a change in temperature?

A tire was fully inflated on a warm day. The following day was quite cold and it was noticed that the tire was 'soft'.

Suggest a possible cause for this behaviour. Plan an experiment or experiments which would support or contradict your theory.

* * *

Fit a flask with a cork, pierced by one hole through which passes a piece of straight glass tubing, Fig. 94. Support the flask so that the outer end of the tube dips below the surface of the water. A little colouring matter added to the water makes for con-

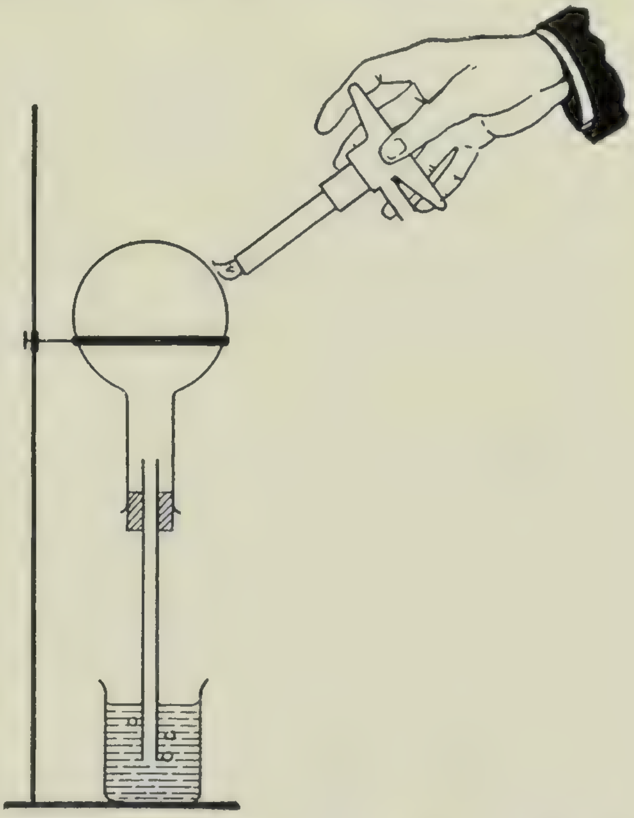


Fig. 94. What is the effect of heating the flask gently? What happens when it is allowed to cool? Account for your observations.

venience of observation. Warm the flask gently. Observe closely what takes place. Remove the source of heat. Soak a cloth in cold water and place it around the flask. What is the result? What are the effects produced, (a) when air is heated, (b) when it is cooled?

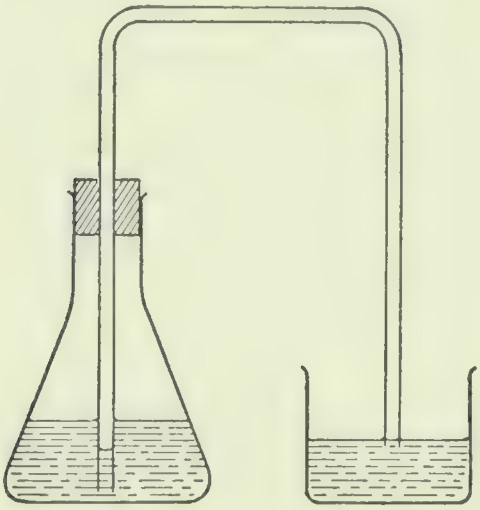


Fig. 95. Describe and account for what happens when the upper part of the flask is gently heated and then allowed to cool.

Exercises:

1. Why does the addition of a well-beaten egg make a cake 'light'? (Hint: When an egg is beaten, a quantity of air is enclosed.)
2. Why is it advisable to beat an egg in a cold room?
3. In the making of 'puff paste' the dough is rolled and folded. Of what benefit is this? (Hint: The rolling and folding cause the enclosure of air.)
4. What happens when air is heated in the hot air furnace?
5. We found that hot air, because it has expanded, weighs less than the same volume of cooler air. Show how the difference in the weight of air at different temperatures is the cause of winds.

C. **MINOR STUDY**: **Wind is the movement of air from a region of high air pressure toward a region of low air pressure.**

When one drinks with the aid of a straw, the beverage moves from the container into the tube because the pressure outside exceeds that within. Air, and other gases, also flow from points of higher to those of lower pressure. For instance, compressed air in a football streams rapidly outward when the tube is untied because the pressure in the bladder is greater than that of the atmosphere.

We have seen that air is set in motion when a difference of temperature exists, but these convection currents are really caused by a difference in pressure because of the greater weight of any volume of cold air compared with that of the same volume of warm air.

PROBLEM I: What is the result of unequal heating of air in adjoining regions?

A wind is really a draught on a large scale. Both are streams of air flowing, just as liquids do, from places of higher to those of lower pressure. When adjacent regions on the earth's surface are at different temperatures, the air over the cooler part has a greater pressure than that over the warmer. As a result, the heavier air flows from the place of lower temperature (and higher pressure) to that of higher temperature (and lower pressure). A reverse current is formed high above the earth's surface.

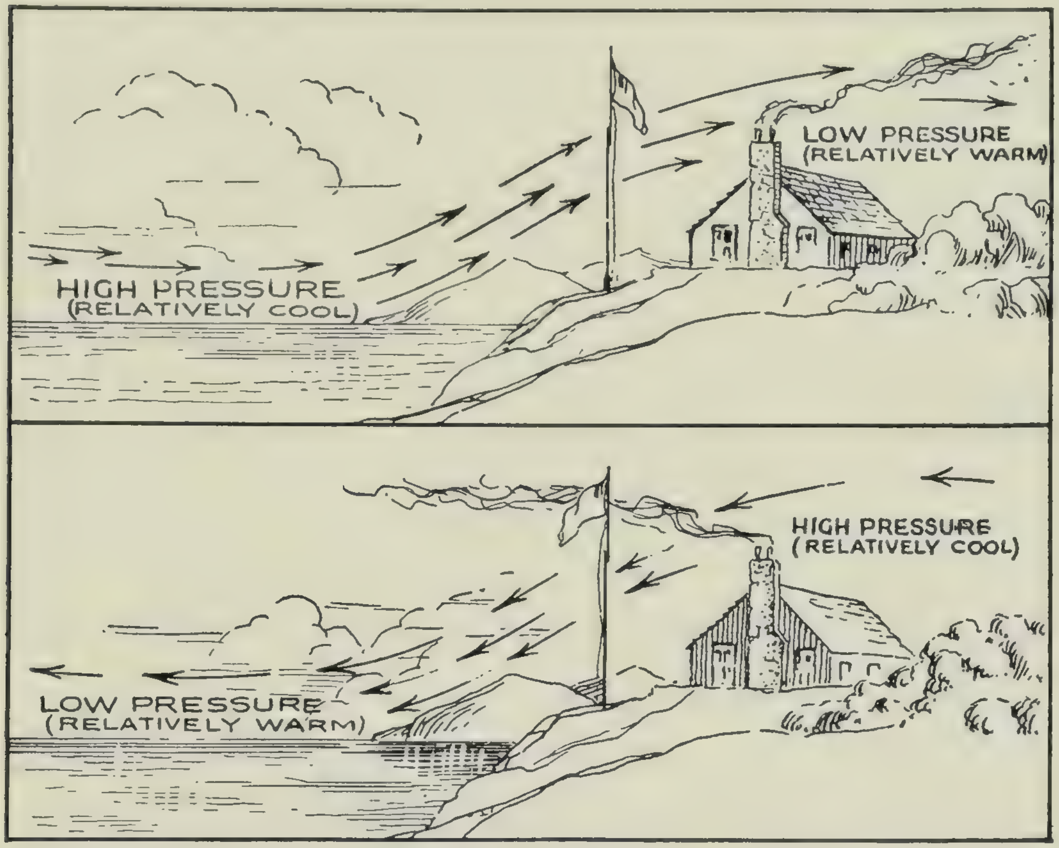


Fig. 96. These land and sea breezes are convection currents.

Land gains and loses heat much more quickly than does water. During a summer day, the land becomes hot, but a large lake or sea is not affected to the same extent. The air over the water is relatively cool and heavy; over the land it is hotter and lighter. Hence, a wind blows from sea to land. At night the land cools quickly, but the sea retains much of its heat. In consequence, the areas of high and low pressure are reversed and the breeze blows from land to sea. In the monsoons, we have an example of land and sea breezes on a large scale.

PROBLEM II: What is the importance of winds?

(a) *Winds and health.*

The circulation of air prevents the excessive accumulation of smoke and other injurious products over large cities. Furthermore, those who live in regions where moderate winds are prevalent are able to lead more energetic and enjoyable lives than those inhabiting places of calm. It is not uncommon for those who are listless or depressed to say that they are "in the doldrums".

(b) *Influence of winds on rainfall.*

When a warm wind blows over a large body of water, it acquires a considerable amount of moisture. Should this air be cooled sufficiently, rain may be produced. Let us take as an example the westerlies, which, in the northern hemisphere, really blow from the south-west. The moisture-laden

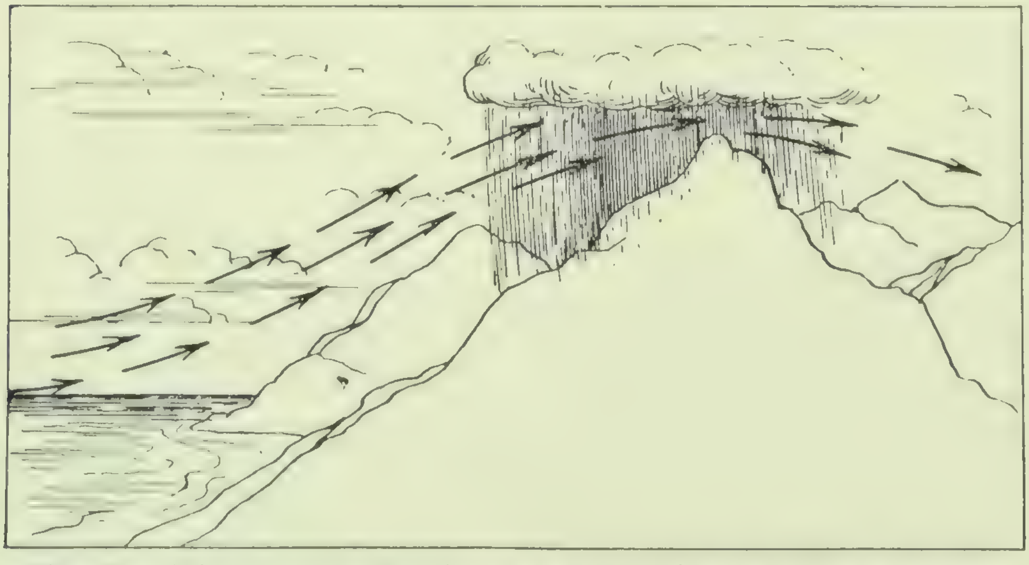


Fig. 97. Distribution of rain on a mountain near the sea coast. Which side of the mountain is receiving the greater quantity of rain?

air from the ocean encounters the Rocky Mountains in British Columbia which deflect it upward. The results are that the air is cooled and a plentiful supply of rain falls on the windward or, in this case, the westerly slope. On the leeward slope and over the prairies there is relatively little rain. It is hardly necessary to dwell upon the differences that this inequality of rainfall brings about in the character of the vegetation and the manner of living of the people. An absence of formidable coastal mountains in Europe enables the westerlies to carry their moisture farther inland.

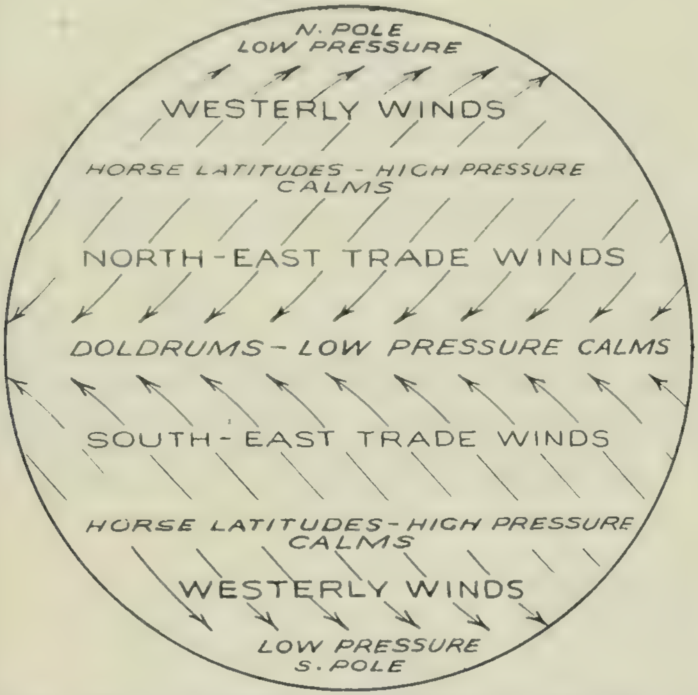


Fig. 98. Diagram representing winds on the earth's surface. Since the surface of the earth is partly land and partly sea, the actual condition is not as simple as that indicated in the figure. [It is said that the Horse latitudes are so called because sailing ships with cargoes of horses were frequently delayed so long that some of the animals were thrown overboard in order to conserve the supply of water.]

During summer, the monsoons from the Indian Ocean blow over southern Asia. These winds carry the moisture which the great agricultural population of India awaits so anxiously.

(c) *Winds and sailing ships.*

Before ships were equipped with engines burning coal or oil, they were propelled by wind or the labour of men. Constant winds like the north-east and south-east trade winds determined trade routes in early days. A ship from England bound for Australia would sail around the Cape of Good Hope, thereby taking advantage of the favourable north-east trade wind and the westerlies of the southern hemisphere. On her return voyage, she would go around Cape Horn because of the westerlies in both hemispheres and the south-east trade winds. In his modern independence of the freakishness of wind we have another example of how man overcomes disadvantages in his natural environment.

A calculation of Mr. J. Patterson gives us an idea of the energy of a wind, and incidentally, of the weight of air. Imagine a rectangular shed a mile long, a mile wide, and a mile high. If this were open on two sides and a twenty mile an hour wind blew through it, the weight of air passing in an hour would be a hundred million tons. The energy of this air would be approximately that obtained from an engine of one million horsepower.

(d) *Windmills.*

For centuries a very small fraction of the mighty energy of winds has been used by men to do useful work on land. The windmill, has been used to pump water and to operate milling machinery. The energy of moving air has been 'harnessed' like that of running water.

(e) *The dispersal of plants by winds.*

Certain fruits and seeds are carried far from the plants which produced them by the wind. Many of the low forms of life which cause diseases in valuable plants are also spread by this agency.

ENRICHMENT SECTION, NUMBER 6.

An explanation of Chinooks.

Chinooks extend eastward as far as Manitoba. Over Alberta they are usually warm, dry westerly winds, often of low but sometimes of high velocity, and exhibiting a characteristic frontal arch.

Chinooks probably give Alberta a greater variety of winter climate than is found anywhere else in the world. These prevailing westerly winds sweep in from the Pacific Ocean. They are warm, moisture-laden winds that hit the mainland of British Columbia. As they ascend the mountains, they become cooler and the water vapour is condensed. Fog forms and is followed by rain and snow. (As the air ascends the mountains, the pressure on it is decreased. Hence, it expands.

This expansion results in cooling at the rate of one degree for each 180 feet of elevation. Condensation of the vapour to rain, and also the formation of snow raise the temperature of the air, the rise being roughly proportional to the amount of snowfall. On the eastern slopes, the pressure on the descending air increases, and the resulting contraction is followed by a higher temperature.) The chinook blows over the foothills and plains as a relatively dry, warm westerly wind.

The rapid melting of the ground snow accompanying a high velocity chinook is due in part to the temperature, but also to the fact that the moisture-laden layer of air in contact with the melting snow is carried away by the wind.

At Edmonton, aviators make weather observation flights each morning that it is possible to do so. With ground temperatures of 30 to 40 degrees below zero, chinooks have been encountered at 2,500 feet with temperature of 45 to 50 degrees above zero. Sometimes, wind velocities range from 70 to 90 miles an hour with virtually no wind at ground level. The pilot takes wind velocities by the simple method of fixing a land mark, throttling down to a point where the ship is "standing still" and then checking the air speed indicator.

Exercises:

1. Relate some experience you have had with a chinook wind.
2. Do these chinook winds, met above Edmonton by fliers, always come down to ground level? State reasons for your answer.
3. Explain why, although chinooks are common to all seasons, temperature differences between the Pacific and the plains at the same latitude become reversed in the summer and only the dry nature of such a wind is noticed.

UNIT 6. MAJOR STUDY: Weather forecasts serve many kinds of interests: They assist industry and farming as well as transportation by sea and air.

PROBLEM I: What is the work of the meteorological service?

Weather forecasting.

Twice every day, at 8 a.m. and 8 p.m., Eastern Standard Time, observations are made at stations scattered throughout

Canada on the atmospheric pressure, the temperature, the wind, the rainfall or snow, and other factors related to weather. This information is communicated by telegraph, telephone, or radio to Toronto and other forecast centres. An exchange of information is made between the offices in Canada and the United States, and from it a chart of the pressure areas and a forecast are prepared. The forecast is very reliable during the following twenty-four to thirty-six hours.

The forecast of the 'Weatherman' in the Meteorological Service is published daily in the newspapers and announced by the Canadian Broadcasting Corporation every evening.

PROBLEM II: Upon what weather factors are the weather predictions based?

After the discovery of the barometer in the seventeenth century, it was observed that the atmospheric pressure varied from day to day even when the instrument was kept at the same place. Moreover, it was noticed that frequently the weather was stormy when the pressure was low, and fine when it was high.

The observations on the type of weather following an increase or decrease of the pressure gave rise to the signs such as 'Stormy', 'Rain', and 'Fine', which may be seen on dial barometers. Generally speaking, these forecasts are far from reliable.

A peculiarity in barometric heights.

The invention of the telegraph made it easy to assemble the readings on the barometer taken in a number of places at the same time. When these figures are written on a map beside the names of the places where they were securd, the arrangement at first sight appears to be a haphazard one, (Figs. 99 and 101). However, if lines be drawn through those places reporting the same pressure, a certain orderliness is revealed, (Figs. 100 and 102). These lines passing through

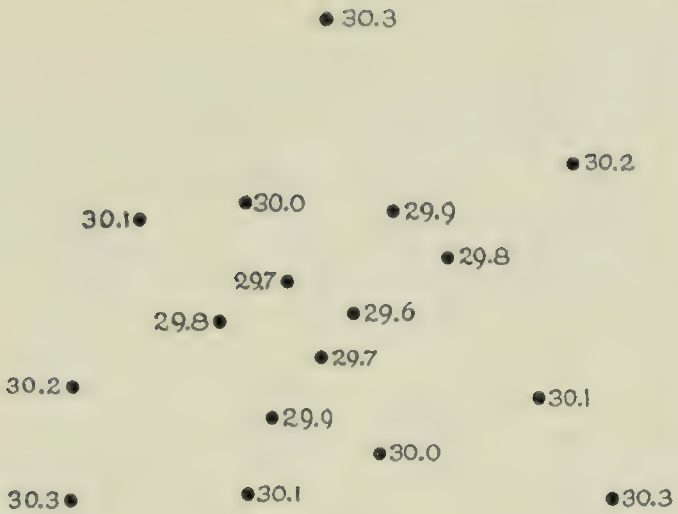


Fig. 99.

A number of readings on the barometer, taken at the same time at places having the same altitude. (When the places are at different heights above sea level, a calculation may be made to obtain the pressures which would be observed if they were all at the same level.) Can you detect any system in this apparently jumbled set of figures?

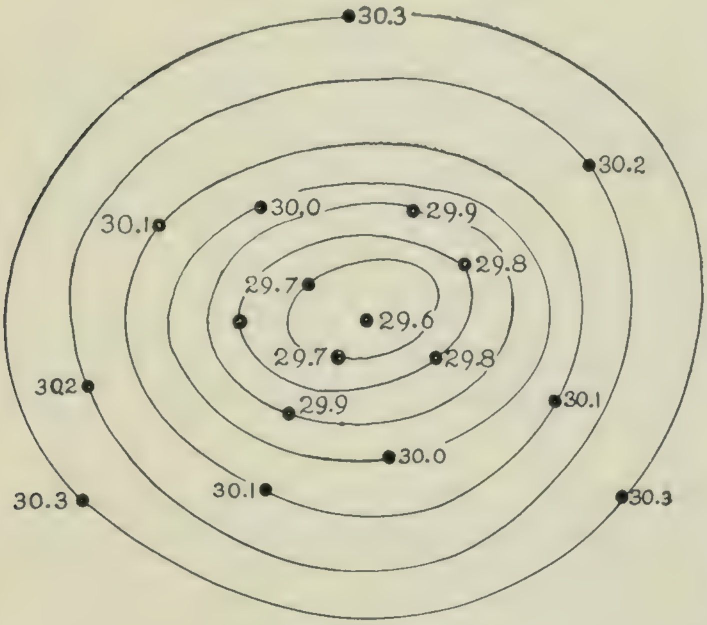


Fig. 100.

If you draw lines through places having the same pressure (Fig. 99), a certain regularity is revealed. Each curve is called an isobar. Where is the pressure least? Find the places where the pressure is greatest.

places which, at some particular time, have the same atmospheric pressure are called isobars. (Gk. *isos*, equal; *baros*, weight.)

A comparison of Figs. 100 and 102 is of interest. In Fig 100 the pressure increases progressively outward from the centre; in Fig. 102 the opposite is true.[1] These arrangements of pressure are quite common. Regions where the system of isobars is of the same type as Fig. 100 are called areas of low pressure; those which resemble Fig. 102 are known as areas of high pressure. Frequently, they are referred to briefly as 'lows' and 'highs'.

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[1] It may be mentioned that simple numbers have been purposely chosen. Actual readings are reported to two places of decimals, and the positions of the isobars representing pressures that differ by one-tenth of an inch of mercury are calculated.

Relation of winds to isobars.

Air, like liquids, flows from places of high pressure to those of low. Hence, we should expect that in a low pressure area, winds would blow towards the centre, and that in a high pressure area, they would blow from the centre outwards. An examination of Figs. 103 and 104 will show that this is approximately true. Due to the earth's rotation, these winds are somewhat deflected, to the right in the North Hemisphere, to the left in the Southern, so that they blow more or less spirally.

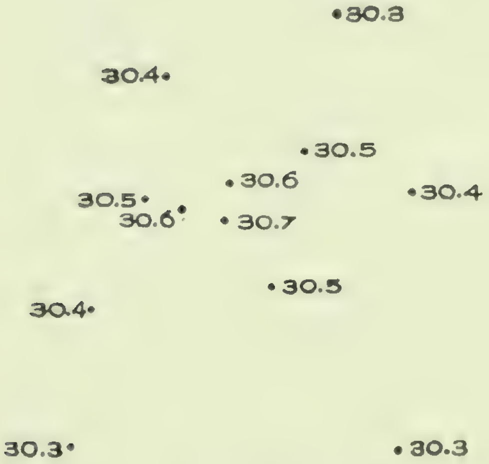


Fig. 101. Another set of atmospheric pressures which at first glance appear to be arranged haphazardly. Like those in Fig. 99, the above barometric heights were read at the same time in different places.

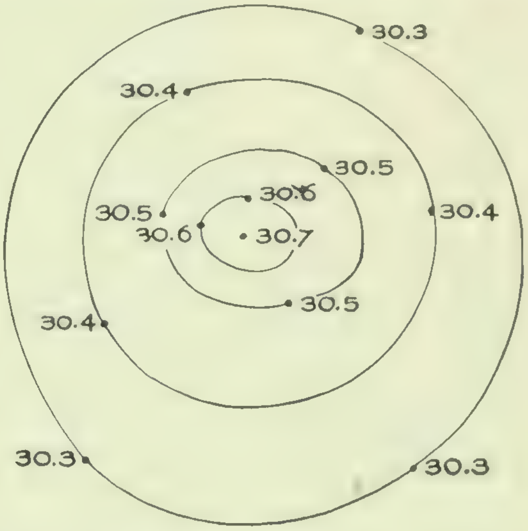


Fig. 102. When isobars are drawn for the pressures given in Fig. 101, an orderliness becomes apparent. Where is the pressure greatest? Where is it least? How does the distribution of pressures differ from that in Fig. 100?

Compare the directions of the two pressure areas with that of the hands of a clock. The counter-clockwise air movements in the 'low' form what is known as a cyclonic circulation; the clockwise spiral in the 'high' constitutes an anticyclonic circulation.

(A simplified account of the low pressure area has been presented. The view, formerly held, that the air moves continuously around the centre, while gradually approaching it, has been abandoned. Now it is known that the air currents have no such symmetry. There are breaks, which, as we shall see, are of the utmost importance in determining the nature of the weather.)

The weather in low and high pressure regions.

(a) *Low pressure areas.*

The mass of air over a low pressure area must be less than that over the surrounding region. Somehow or other there is a withdrawal of gas at the top. That which is removed gathers elsewhere, giving rise to a region of high pressure. To take the place of the gently ascending air there is, of course, an in-flow.

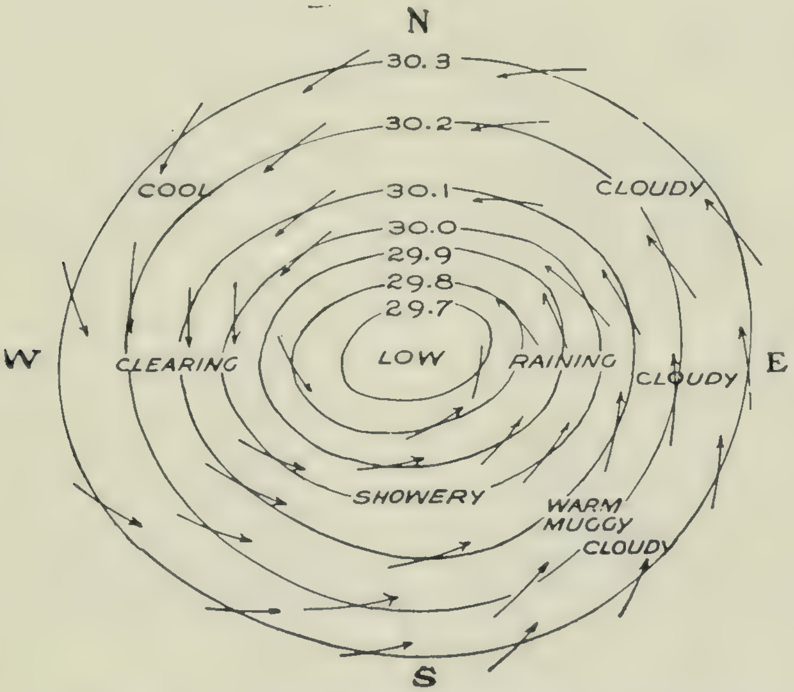


Fig. 103. The winds in a low pressure region.
Arrows fly with the wind.

Some figures given by Sir Napier Shaw in describing a very modest 'low' may be of interest. It had a diameter of some 900 miles. In order that it might be formed 70,000,000,000 tons of air were withdrawn in appromixately six days. This air was restored again in about three days. The low pressure area contained about 700,000,000 tons of water vapour!

Generally speaking, the air in a low pressure area is relatively warm and moisture-laden. As it rises, the pressure on it becomes less. Consequently, like air escaping from a football bladder, it expands. When a gas expands, it is cooled. (Air permitted to escape through a valve of an automobile tube has a slightly lower temperature than that inside.) If the cooling proceeds far enough, the water vapour present may condense and form clouds, rain or snow. Hence, clouds and rain or snow usually occur in low pressure areas.

(b) *High pressure areas.*

In the 'high', cool air settles down and flows out from the centre. As the descending air approaches the earth, the pressure on it increases. It was pointed out that an expanding gas is cooled; the reverse occurs when there is compression. In other words, the increasing pressure on the descending air in the 'high' causes a rise of temperature. Hence, instead of producing condensation, such as takes place in the 'low', the air causes clouds to change back into vapour. The result is that clear weather follows.

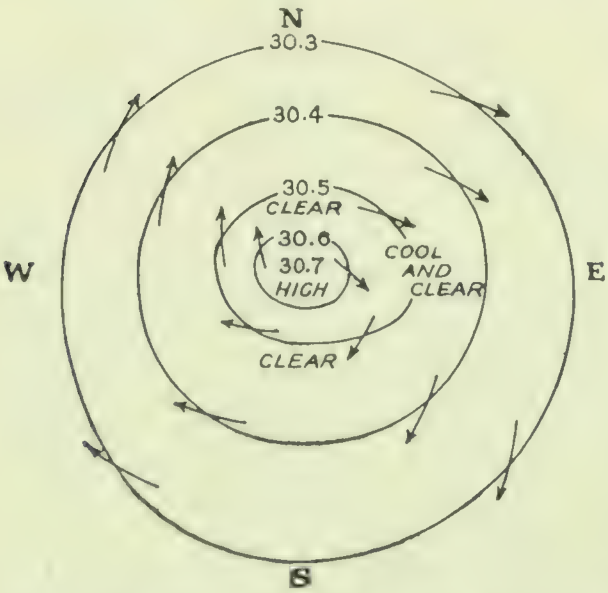


Fig. 104. The winds in a high pressure area.

A continental parade.

Those great aerial disturbances, the 'lows' and 'highs', move in an easterly direction across this continent at a rate which varies from approximately twelve to forty miles an hour, and has an average of about twenty-five. A number of them enter the Atlantic Ocean by way of the St. Lawrence Valley. One 'low' which originated in Montana on the twenty-third of February, 1925, travelled more than twenty-one thousand miles and, on its second round of the earth, vanished in the Gulf of St. Lawrence on the twenty-third of March.

Two great air currents.

In recent years, meteorologists have given increasing attention to conditions in the upper air. They realized that it was necessary for man, a creature of the 'ocean' bed, to learn more about the vast body of gas far above him. By means of kites, balloons, aeroplanes, and radio, they have sought to unravel the mysteries of the upper atmosphere.

One result of these investigations is the discovery that in temperate regions there exist two air currents. One, called the polar current, is cold and dry; the other, known as the equatorial current, is warm and moist. Just as hot and cold water may be present together in a bathtub, so these two great air currents may exist side by side with very little mixing taking place.

The line of separation is known as the 'front'. It is due to the discovery of these currents that the older idea of the continuous circulation of the air in a low pressure region is no longer held; the circulation is discontinuous.

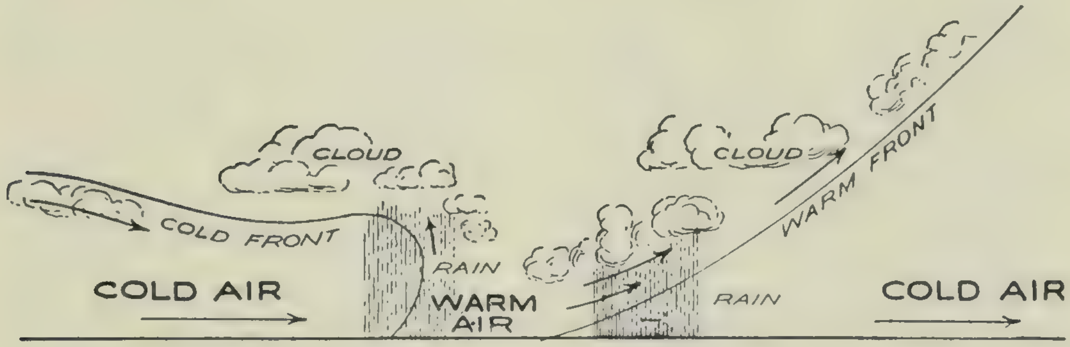


Fig. 105. Vertical section of a 'low'. The warm equatorial current drives back the cold air, rises above it, and is cooled. The advancing polar current undercuts the warm air, forcing it upward. Bad weather occurs at the line of separation of the two currents.

In those parts lying within the territory of the equatorial current, hot sultry weather is generally experienced. When

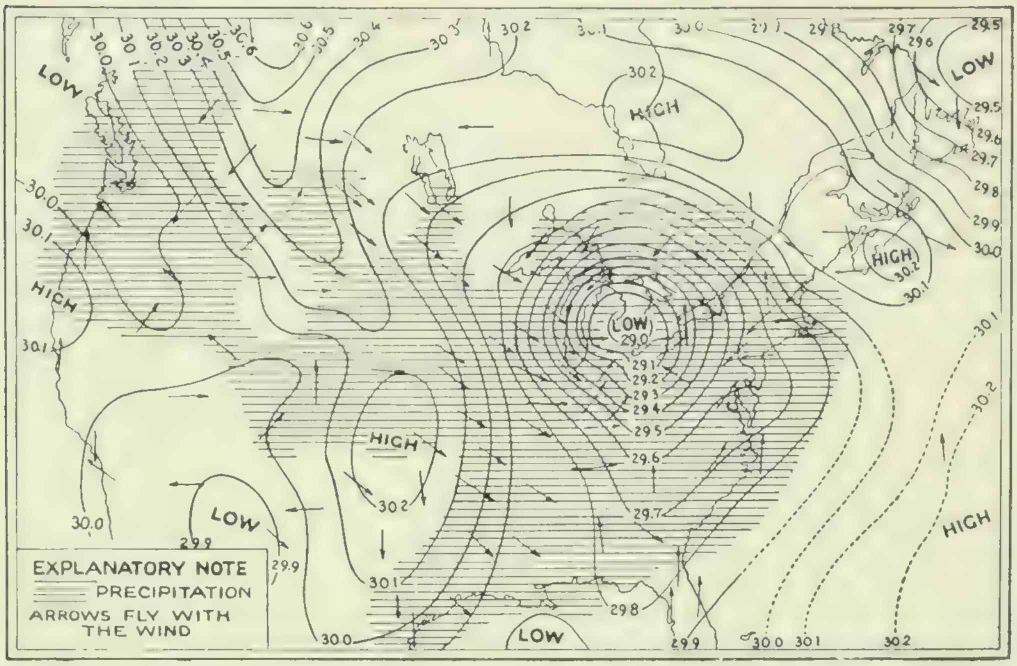


Fig. 106. Weather map for a day in February. Find the "deep disturbance passing northeastward across the Great Lakes."
(*Based on a weather map of the Meteorological Service of Canada.*)

FORECASTS

Lower Lake Region and Georgian Bay. West to northwest gales; becoming much colder tonight and Wednesday with some snow, chiefly in west portion.

Northern Ontario. Strong northeast to northwest winds with snow. Wednesday, northwest winds; partly cloudy and decidedly cold; snowflurries.

Ottawa and Upper St. Lawrence Valleys. Strong east to southeast winds with snow or sleet, followed by strong northwest winds and much colder again late tonight and Wednesday.

Lower St. Lawrence Valley. Strong northeast winds with snow, probably part sleet. Wednesday, strong westerly winds; partly cloudy and cold with snowflurries.

Northwestern Quebec. Lake St. John. Strong easterly winds with snow; colder late tonight. Wednesday, strong northwest winds; partly cloudy and cold; snowflurries.

Gulf and North Shore. Strong easterly winds or gales with snow tonight and part of Wednesday.

Maritime Provinces. Easterly gales with snow and sleet tonight and part of Wednesday.

FORECASTS

Lake Superior. Strong northeast to northwest winds; cloudy and cold with some snow, chiefly in east portion. Wednesday, northwest winds; partly cloudy and decidedly cold with snowflurries near the Soo.

Kenora and Rainy River. Northerly winds; fair and decidedly cold today and Wednesday.

Western Provinces. Mostly fair and decidedly cold today and Wednesday.

Grand Banks. Fresh to strong westerly winds, becoming variable on Wednesday; fair and moderately cold today and most of Wednesday.

Newfoundland. Fresh to strong northwest winds, becoming variable on Wednesday; partly cloudy today and most of Wednesday with much the same temperature; local snowflurries.

SYNOPSIS OF WEATHER CONDITIONS

A deep disturbance, passing northeastward across the Great Lakes, has caused snow and sleet in Ontario and Western Quebec, while it has been fair and cold in Eastern Quebec and the Maritimes. High pressure with decidedly cold weather covers Northwestern Canada and the greater part of the Western States.

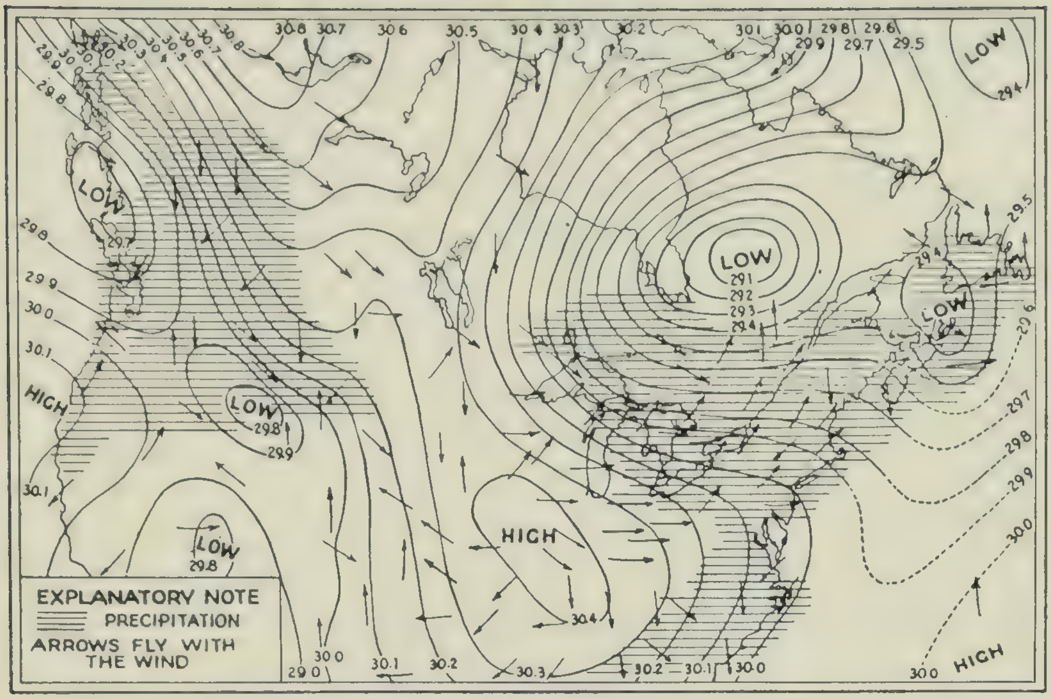


Fig. 107. Weather map for the following day. Note the change in position of the "deep disturbance".

(Based on a weather map of the Meteorological Service of Canada.)

FORECASTS

Lower Lake Region. Strong westerly winds, decreasing tonight; fair and decidedly cold today and Thursday; probably light snow in west portion.

Georgian Bay. Strong westerly winds, decreasing tonight; partly cloudy and decidedly cold today and Thursday with local snow.

Northern Ontario. Strong northwest winds; mostly fair and decidedly cold today and Thursday.

Ottawa and St. Lawrence Valleys. Strong westerly winds; fair and colder tonight and Thursday.

Northwestern Quebec. Lake St. John. Strong westerly winds; mostly fair and decidedly cold tonight and Thursday.

Gulf and North Shore. Strong westerly winds; partly cloudy and cold tonight and Thursday.

Maritime Provinces. Fresh to strong westerly winds; fair and cold tonight and Thursday.

Lake Superior. Strong northwest winds, decreasing tonight; fair and decidedly cold tonight and Thursday.

FORECASTS

Kenora and Rainy River. Fair and decidedly cold tonight and Thursday.

Manitoba. Fair and decidedly cold today and Thursday.

Saskatchewan and Alberta. Mostly fair and decidedly cold today and Thursday.

Grand Banks. Strong southerly to westerly winds with snow, probably part sleet. Thursday, strong westerly winds; partly cloudy.

Newfoundland. Fresh to strong winds, shifting to westerly tonight; occasional snow. Thursday, strong westerly winds; partly cloudy and moderately cold with snowflurries.

SYNOPSIS OF WEATHER CONDITIONS

Pressure is low over Northern Quebec and the Gulf of St. Lawrence and the weather has been stormy throughout Eastern Canada with snow and sleet. High pressure and decidedly cold weather cover Northwestern Canada and a large portion of the Western States. It has become much colder in Ontario and Western Quebec.

the advancing warm air encounters the cold, it rises over it and is cooled. The results are that condensation takes place and clouds and rain are produced.

When the polar current first flows over a region, the weather is usually cold and the sky clear. In winter we say that there is a 'cold wave'. When the advancing 'cold front' meets the warm equatorial air, it pushes its way underneath. The warm air is forced upward and stormy weather follows. In this region we may have squalls, thunder, hail and even tornadoes.

The polar and equatorial currents have been likened to conflicting armies, one from the north, the other from the south. Where they encounter each other, those disturbances which we called 'changes in the weather' are caused.

Importance of air movements.

In another part of this book we shall refer to the enormous amount of water required by our crops and other vegetation. All of this liquid is derived from the water vapour in the air. Whence does this vapour come?

In the main, it is derived from the great bodies of warm water which lie within the tropics. By the movements of the air, this vapour is transported thousands of miles. Then it is condensed to supply us with the rain on which, in large measure, the prosperity of our country depends.

* * * *

A weather map may be obtained free of charge, by science teachers, from The Controller, Meteorological Service of Canada, Toronto.

(1) Compile a list of occupations and sports which are dependent upon weather conditions.

(2) Man cannot prevent unfavourable weather but there is much he can do to lessen its influence. Give a number of examples.

(3) The course of history has been altered at times by the weather. What instances have you encountered in your reading?

(4) In the verses quoted below Dr. Edward Jenner (1749-1832) gave his reasons for declining the invitation of a friend to make an excursion with him. The observations were made in England. How many valid ones of a similar nature can you make in Canada?

The hollow winds begin to blow,
The clouds look black, the grass is low;
The soot falls down, the spaniels sleep,
And spiders from their cobwebs peep.
Last night the sun went pale to bed,
The moon in halos hid her head.
The boding shepherd heaves a sigh,
For see, a rainbow spans the sky!
The walls are damp, the ditches smell,
Closed is the pink-eyed pimpernell,
Hark how the chairs and tables crack!
Old Betty's nerves are on the rack;
Loud quacks the duck, the peacock's cry,
The distant hills are seeming nigh.
How restless are the snorting swine!
The busy flies disturb the kine,
Low o'er the grass the swallow wings,
The cricket, too, how sharp he sings!
Puss on the hearth, with velvet paws,
Sits wiping o'er her whiskered jaws;
Through the clear streams the fishes rise,
And nimbly catch the incautious flies.
The glow-worms, numerous and light,
Illumed the dewy dell last night;
My dog, so altered in his taste,
Quits mutton-bones on grass to feast,
'Twill surely rain—I see with sorrow
Our jaunt must be put off tomorrow.

(Abridged)

TOPIC IV—ANIMAL LIFE

UNIT 7. MAJOR STUDY: Our fellow inhabitants of the earth.

A. MINOR STUDY: Living things and non-living things.

What do we mean when we say that some things are alive while other things are not?

PROBLEM I: Does movement distinguish the living from the not-living?

Movement may distinguish a dog from a block of ice, but not from a moving flag. We agree that a rose is alive, yet there may be no apparent movement.

Going further with the idea of movement, we may say that a dog possesses the power to move of itself. A flag is moved by the breeze. It is the breeze that does the moving and not the flag itself.

Again, a dog can replenish this motive power by eating what we call food, and is able to go in search of food. A flag is helpless to cause the breeze to blow in order to provide movement.

A dog must have oxygen to breathe and, if necessary, will make an effort to avoid being suffocated. Neither the flag nor the ice is affected by suffocation.

PROBLEM II: What are the real differences between what is living and what is not living?

All living things have certain urges. A dog feels hunger pains and desires to eat and, of its own accord, it proceeds to satisfy the hunger urge. The dog is sensitive to many other arousing agents among which are touch, light, smell, taste, and hearing. To be sensitive to an urge and to react to this urge are characteristics peculiar to living creatures but not to non-living things.

All things wear out in time. Living things have the power to repair the ravages of time by growth. The dog grows hair, toenails lengthen, wounds heal and new skin replaces old. A non-living thing does not possess this power to repair itself. This growth is reflected in the gradually increasing size of an animal or a plant. The dog grows from a pup to an adult, while the seed of a plant germinates and produces the seedling that grows into a mature plant.

A final distinction for use at present, is that living things are able to give birth to young. We have played with a kitten or pup; we have also watched a seed germinate and produce a seedling. The pup comes from the body of the mother dog, while the seed comes from the flower of the plant. Neither the block of ice nor the flag can reproduce itself in this manner.

PROBLEM III: What is an animal?

If we examine particular plants and animals, we shall note some movement in members of both classes. Usually, however, movement is more pronounced among animals.

We shall discover that both plants and animals respond to similar needs, but that the animal is generally more sensitive than the plant.

While uric acid is present in all animals and is not present in plants, the chief distinguishing characteristic is the ability of plants to manufacture their own food aided by sunlight. Animals are dependent for their sustenance on this food manufactured by plants.

Note: Remember that some plants do not possess chlorophyll and therefore do not manufacture food.

Examine a mushroom or toadstool.

(i) What is the colour of the plant?

(ii) See if you can identify the parts shown and named in the illustration.

(iii) Examine the soil in which the mushroom was growing and see if you can recognize any decaying vegetation.

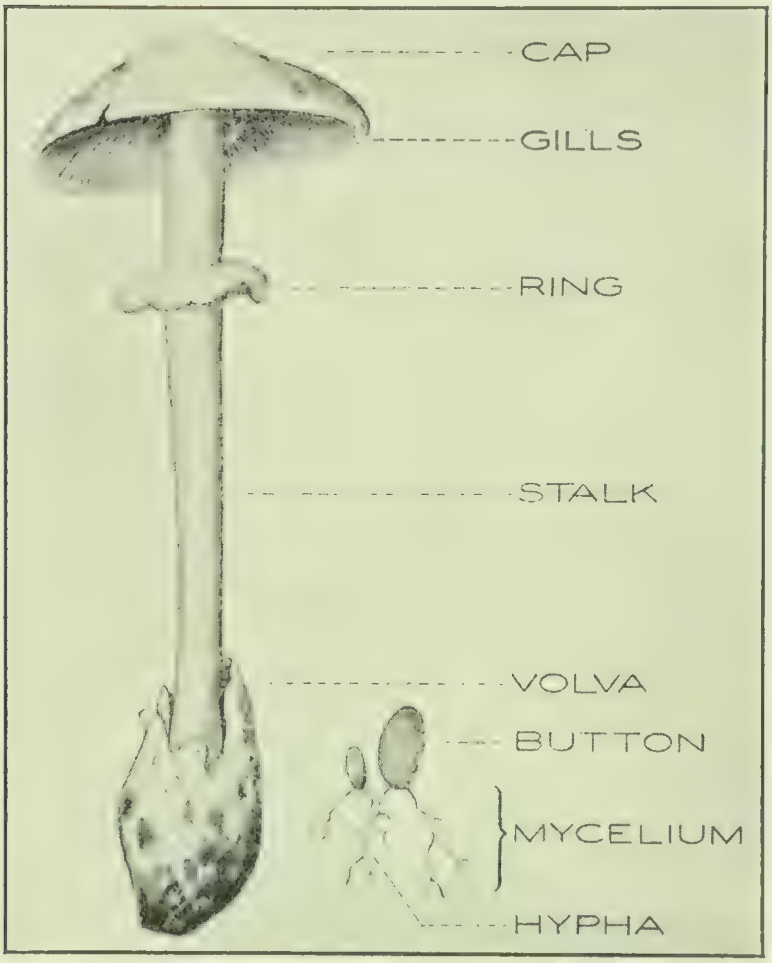


Fig. 108. The parts of a mushroom. This is the Destroying Angel, a poisonous form.

PROBLEM IV: How did the taming of wild animals affect civilization?

There are reasons for believing that primitive man obtained his food by hunting, fishing and collecting shell-fish, long before he acquired the art of taming animals and raising them in captivity. Because of his relative slowness, and the crudeness of his weapons such a living must have been frequently meagre and always uncertain. There must have been many a feast, many a famine. How our ancestors learned to domesticate some of the animals around them is an interesting subject for study but one concerning which we have no reliable knowledge. The taming of animals, although not so important as the later discovery of grain cultivation, was an achievement the importance of which can hardly be exaggerated. It meant the release from a poor existence; domesticated herds were the equivalent of a bank balance in modern times. Of necessity, these primitive men were nomads, moving to fresh grazing grounds as old ones became exhausted, a mode of living still followed by a number of Asiatic peoples. This pastoral life did not permit the establishment of villages or even of permanent homes, nor did it encourage the accumulation of household goods beyond the barest necessities. Permanent settlements and improved furnishings were among the results which followed when men began to plant crops. However, pastoral men had marked advantages over the hunter. Apart from his superior position in the matter of food and clothes, the herdsman had more leisure for thinking about the things around him and, as a result, was able to make a greater contribution to civilization.

PROBLEM V: What is the value of domesticated animals to man?

It is hardly necessary to dwell upon the importance to our food supply of cattle, sheep, pigs, poultry and bees.

In addition to beef, butter and cheese, a host of other useful products are derived from cattle. One of the most important is leather, the many uses of which need not be listed. From the bones of cattle is made artificial fertilizer containing the phosphorus essential for plant life. Other articles manufactured from bones are gelatine, buttons, pipe stems, toothbrush handles and crochet hooks. Horns are converted into combs, handles for knives and umbrellas. From the hair inside the ears, artists' brushes are made, and the switch of the tail finds a place in mattresses and upholstery. Casein, an ingredient of milk, enters into the manufacture of mucilage, paints, cigarette holders, buttons, combs, phonograph records, telephone receivers and paper sizing. Lactose, another component of milk, is an ingredient of certain proprietary foods; it is used in coating pills and in the manufacture of some explosives. Insulin, employed in the treatment of diabetes, is made from an internal organ, the pancreas. Rennet comes from the stomach of the calf. Among the remaining articles obtained wholly or in part from cattle are oleo-margarine, glycerine, soap, candles and glue.

No emphasis on the value of wool is necessary.

We know of the use of horses, ponies, donkeys, oxen, yaks, camels, dromedaries, llamas, reindeer, tame elephants and dogs in transportation or in farming operations. The elephant is no longer used in warfare and it is certain that with the increasing mechanization of armies fewer and fewer horses will be needed.

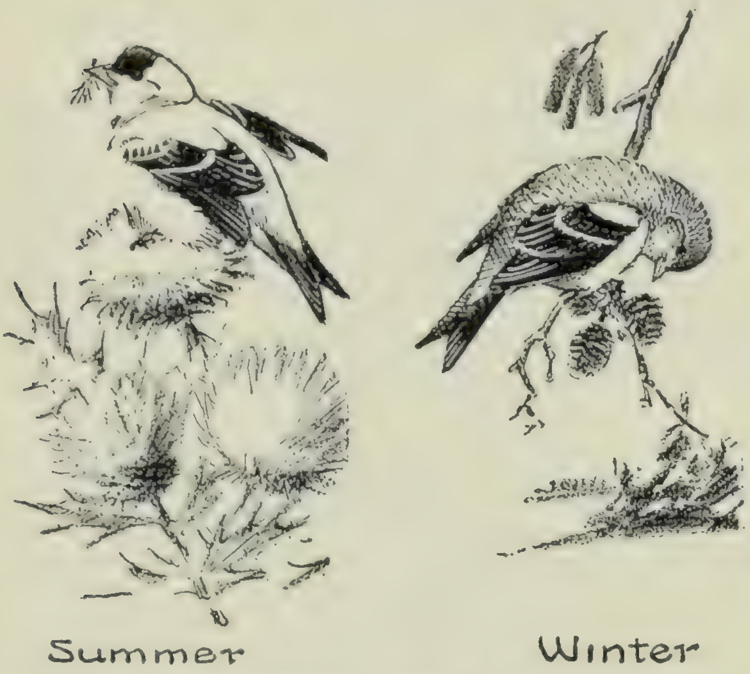
The value of dogs and cats as household pets and destroyers of vermin should not be overlooked. The former have accompanied hunters from time immemorial. Dogs and white rats have been much used in experiment work for the discovery of techniques to alleviate human suffering and in researches on diet.

PROBLEM VI: What is the value of wild animals to man?

The two oldest Canadian industries, trapping and fishing, were dependent upon animal life. They continue to occupy a considerable place in the economic life of this country. We think of the large sum of money spent yearly by visitors from the United States who are attracted to Canada by the splendid opportunities for shooting and fishing. We should not overlook the betterment of health which living out of doors confers on those who hunt with the gun or camera.

An ever-increasing number of persons find pleasure in observing the habits of wild creatures, more especially those of birds. These feathered animals have claims for our high regard other than the possession of fine plumage, musical talent, and sprightly manners. They are reliable and tireless allies of man in his unceasing warfare with insects; also, by devouring an immense quantity of weed seeds they help to save our fields from infestation. Birds perform other services for man. Some, like the herring gull and the osprey, are scavengers. Gulls resting on rocks during fog have by their shrill cries unwittingly warned fishermen of approaching danger. At other times, by their keen interest in the surface of the water, they indicate the presence of schools of fish.

Certain kinds of insects perform a valuable service to us by reducing the numbers of pests which devour our crops. We shall return to this matter in a later chapter.



(*Courtesy Nat. Assoc. of Audubon Soc.*)

Fig. 109. The American goldfinch, or wild canary, is a tireless destroyer of weed seeds.

Exercises:

1. The accompaning article from "Popular Mechanics" is a splendid study in animal-man relationship. Read it very carefully.

FASHION REQUIRES ZOO TO CLOTHE WOMAN.

If all the animals and reptiles that are called on to supply a part of the raiment of modern woman were gathered under one roof, the collection would represent a well-stocked menagerie. To begin with, the felt hat that Dame Fashion decrees may have had its origin in a rabbit, muskrat or beaver. The hair and fur are removed from the skins, separated by a blower and from the fur the hats are made. South America, Canada, Australia and other places supply hat fur. For the fur coat there seems no limit upon the animal range. It may be made from the pelts of lowly rabbits or from the more expensive sable, ermine, leopard or seal. Silkworms supply dress materials, oysters furnish pearls, cloth fabrics may come from the wool of sheep or the hair of the llama, gloves may once have been the skin of the chamois, some rare deer or the pig, and for shoes the modern miss goes to the reptile house.

Snakes, lizards and crocodiles help to supply footwear and the soles represent the hides of cattle that roamed the plains.

2. Study the newspaper clipping reprinted below. Consider other animals, such as the cow, and make a list of the uses man makes of them.

WHAT USE DOES MAN MAKE OF SHARK?

"Its fins provide the Chinese with one of their most highly-prized (and priced) dishes, and with gelatine; its teeth are used by jewellers; its liver and fat are turned into oil; its carcass makes food for fowls and cattle; its head is turned into glue and its hide and stomach provide leather that is more than five times as durable as the best calf. The rough skin of certain species is used as shagreen."

PROBLEM VII: How may animals be injurious?

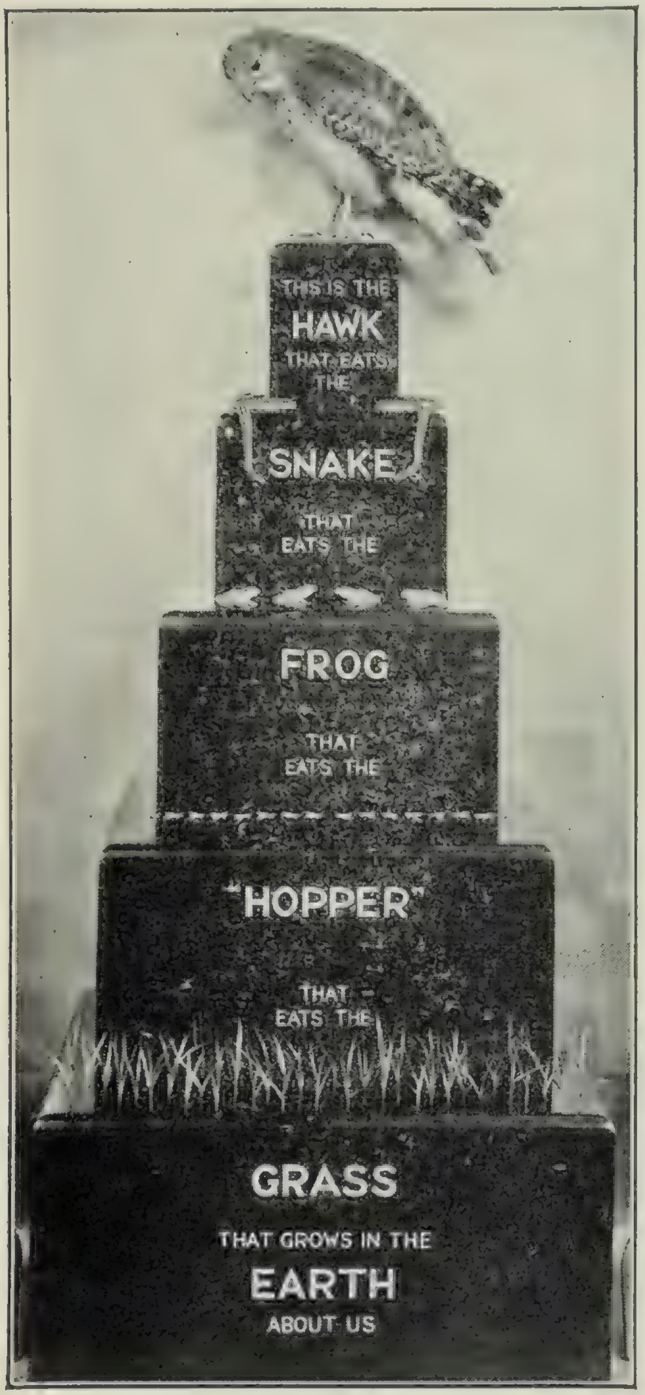
Great quantities of food intended by man for his own use are devoured or polluted by rats, mice and insects. Clothes and rugs are ruined by that household pest, the clothes moth larva. Travel is sometimes an annoying or even a dangerous experience because of the attentions of mosquitoes, poisonous snakes, and, in tropical countries, leeches. We have referred to the part which some animals play in advancing medical science, but we must not overlook the transmission of disease by rats, and house-flies and other insects.

B. MINOR STUDY: Animals and plants are linked together.

PROBLEM I: What is a food-chain?

To many a terror-stricken little animal death comes in the form of a slender, remorseless creature. The weasel's eyes, bright with the lust for murder, are set in a face of fury. Agile almost beyond belief he darts hither and thither, vanishing and re-appearing as though to be visible or invisible depended on the whim of a moment. He is one of those whose business is his hobby. Other animals may kill to eat, but to him murder is a fine art. Long after his thirst for blood is satisfied he slays because it is his pleasure. He invades the poultry house, climbs trees in pursuit of squirrels and robs birds' nests. Chipmunks, rabbits, rats and mice are slaughtered at every opportunity. Even cannibalism is included among the grim diversions of the weasel.

What is the food of those creatures which the weasel seeks so persistently and slays so relentlessly? Much of it consists of plant products such as buds, bark, berries, nuts and grain. We must admit that the sprightly chipmunk does not confine himself to a vegetable diet. He adds insects to his menu, and enjoys a meal of young birds or mice whenever an opportunity presents itself. On what do these insects, birds and mice live? The insects may feed on plants; the birds are probably dependent on insects or seeds, the mice on grass, clover, seeds and bark. *In short, if we were to make a list of the different foods eaten during their lifetime by the victims of our weasel, we would find that they consisted either of some product derived from plants, or of some animal which depended for its living on vegetation.*



(Original in Royal Ont. Mus. of Zoology.)

Fig. 110. Nature's "House that Jack built"; an example of a food chain.

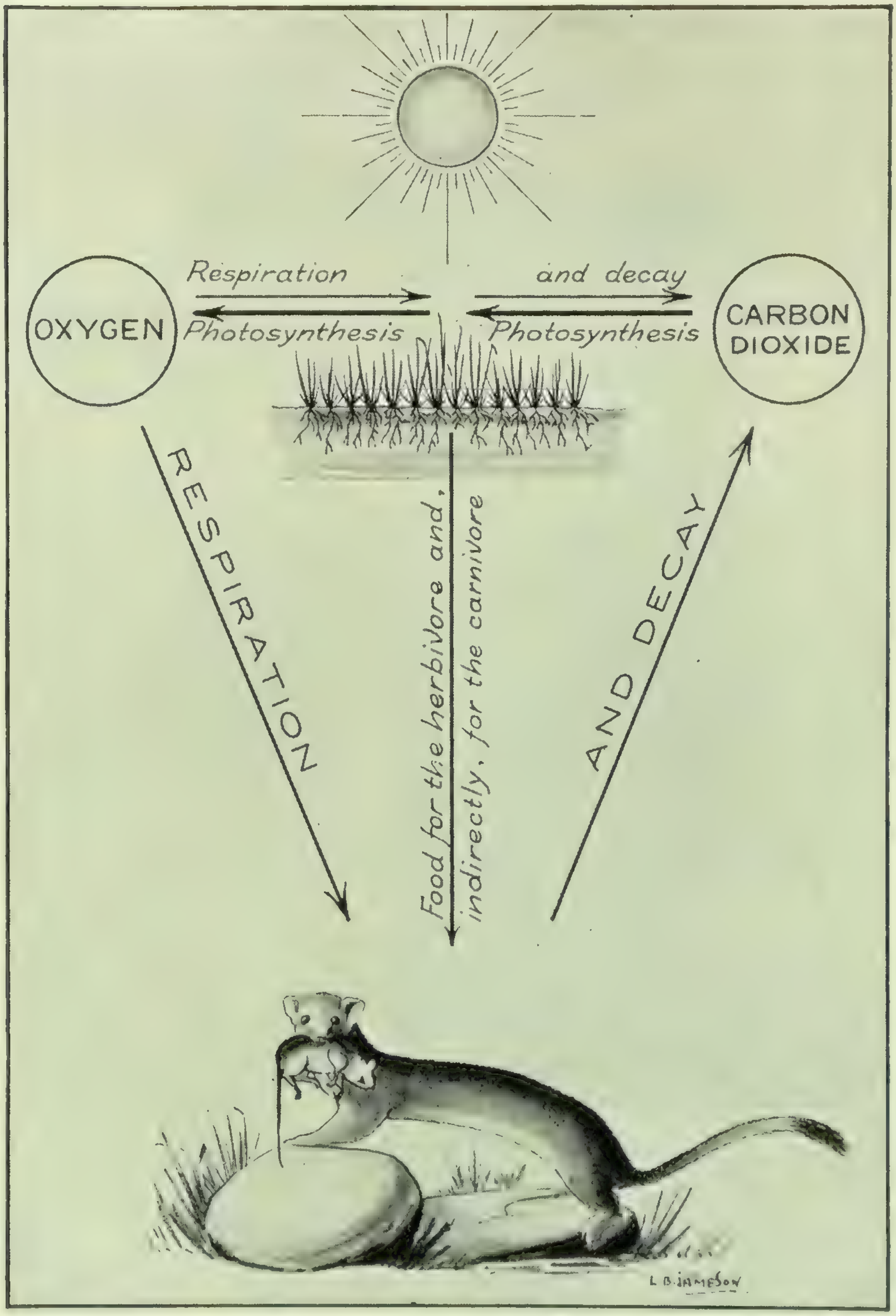


Fig. 111. The flesh-eaters depend upon plant-eaters for their existence; sunlight, carbon dioxide, water and mineral salts are necessities for green plants.

We have taken the weasel to illustrate the final dependence of all animals on plant life. There are millions of other food-chains. Grass is changed into rabbit, and rabbit into lynx; plant juice is converted into aphid, aphid into ladybird beetle, beetle into bird; dead leaves are transformed into earthworms, and they, in turn, into moles and robins.

PROBLEM II: How are animals dependent on sunlight and chlorophyll?

Here we may recall that green plants are able to construct food substances from carbon dioxide and water during the hours of sunshine. With this manufactured food and small quantities of nitrogen, sulphur and other substances derived from the soil solution, the plants are able to live and grow.

Since human beings and animals are dependent upon green plants, it is clear that chlorophyll and sunshine are among our few real necessities.

After death, the materials of which plants and animals are composed return to the soil and air, to be used over and over again by other plants and animals.

PROBLEM III: What exchange of gases takes place?

Human beings and animals make a return to the green plants on which their existence depends. The carbon dioxide in exhaled breath is used by plants as one of the raw materials in photosynthesis (food manufacture). However, plants perform another service; when manufacturing food materials they release a waste gas, oxygen, equally needful for their own breathing and for that of animals. This exchange of gases prevents the quantity of carbon dioxide in the atmosphere from increasing, and the quantity of oxygen from diminishing.

The aquarium and its inhabitants.

Both salt water and fresh are the habitats of countless numbers of animals. In silence, they complete their scheme of existence. Their days are filled by the endless search for food, the ambush, the pursuit, the battle and the hair-breadth escape. Fully occupied with their own concerns, they know

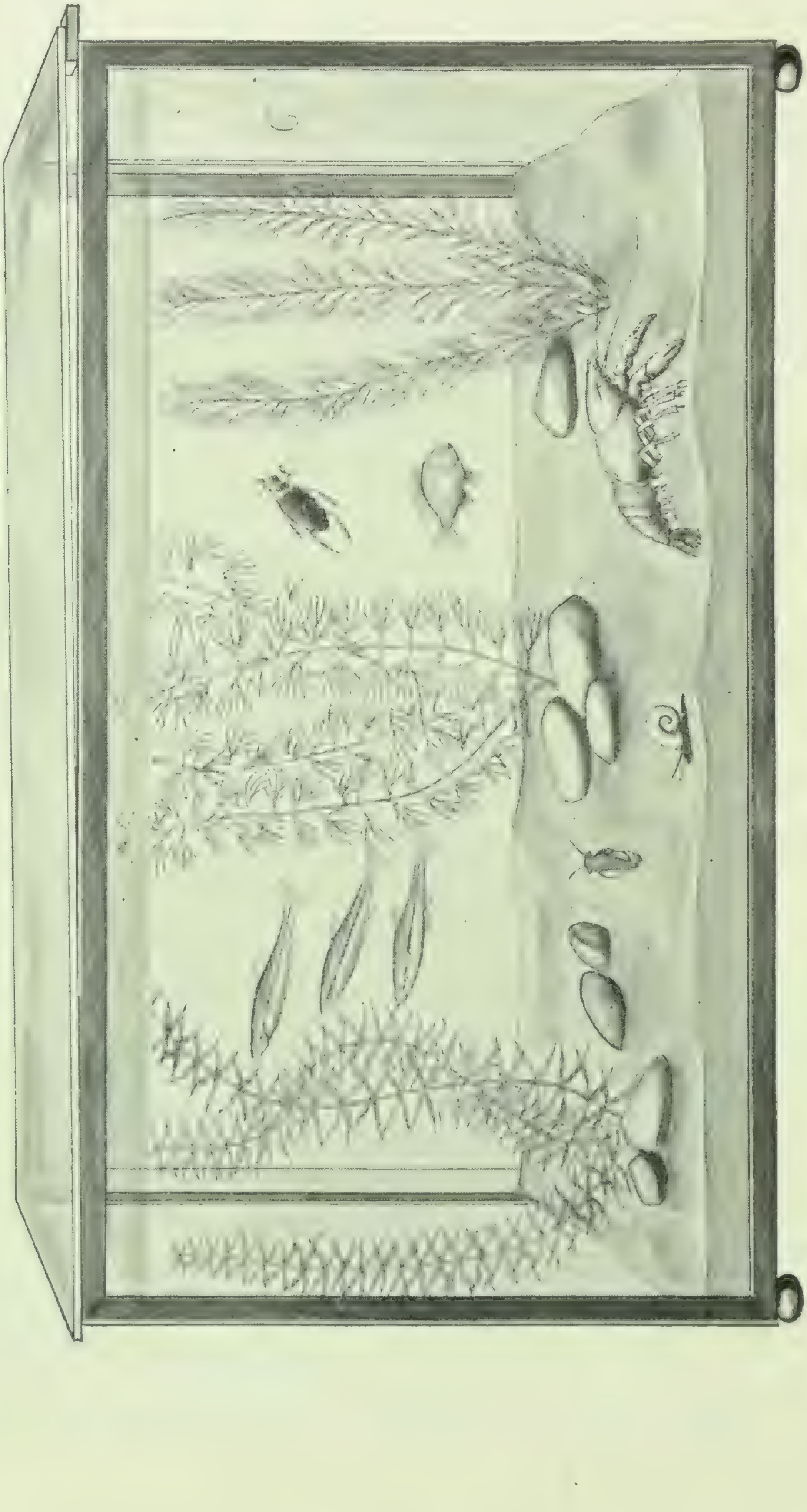


Fig. 112. An aquarium.

nothing of the affairs of man. On the other hand, we find the story of their way of living an extremely interesting one, and see much in their behaviour that reminds us of our own.

A number of aquatic animals may be kept alive in the classroom, where their habits may be conveniently observed. For this purpose we need a water-tight container.

Starting an aquarium.

Provided that it does not leak, any glass jar will serve our purpose. Those with flat sides are preferred because of the distorted vision through curved glass. The greater the surface area per gallon of water, the more remote will be the possibility of some or all of the animals dying, and so, when one has choice, it is recommended that a container with a width not less than the height be selected.

Sand for the bottom of the tank should be washed until no trace of turbidity remains. It will be sufficient if the layer of sand be about an inch and a half in thickness. A few stones help to give a natural effect.

Unless it has been heavily treated with chemicals, tap water may be used for fish, crayfish, snails, clams and beetles. For some of the smaller animals it is advisable to use pond water.

Aquatic animals, like others, need air. Those that do not come up to the surface to breathe obtain air from the water, where it is dissolved just as sugar dissolves in tea. How does air get into the water? Some enters at the surface; so we see why it is desirable to have a container which exposes a maximum area of water. There is another source of oxygen; the gas is released by green plants during photosynthesis.

Canada waterweed (*Elodea*) and water milfoil (*Myriophyllum*) are excellent aquarium plants. After a few inches of water have been poured in, planting should be done. Plants with roots should have them buried in the sand. In the case of others, a piece of lead may be fastened to the end of the stem. Water should now be poured in carefully until the tank is almost full.

A glass cover keeps out dust and checks evaporation. It may be raised a little at one end.

The green algal growth is one of the aquarium keeper's troubles. Certain of the animals help to reduce it, but even this whole-hearted co-operation is unavailing at times. Too much of this growth is an indication of embarrassingly healthy conditions caused by too much sunlight. One should seek light conditions adequate to the growth of the aquarium plants, but unsuited to excessive development of algae.

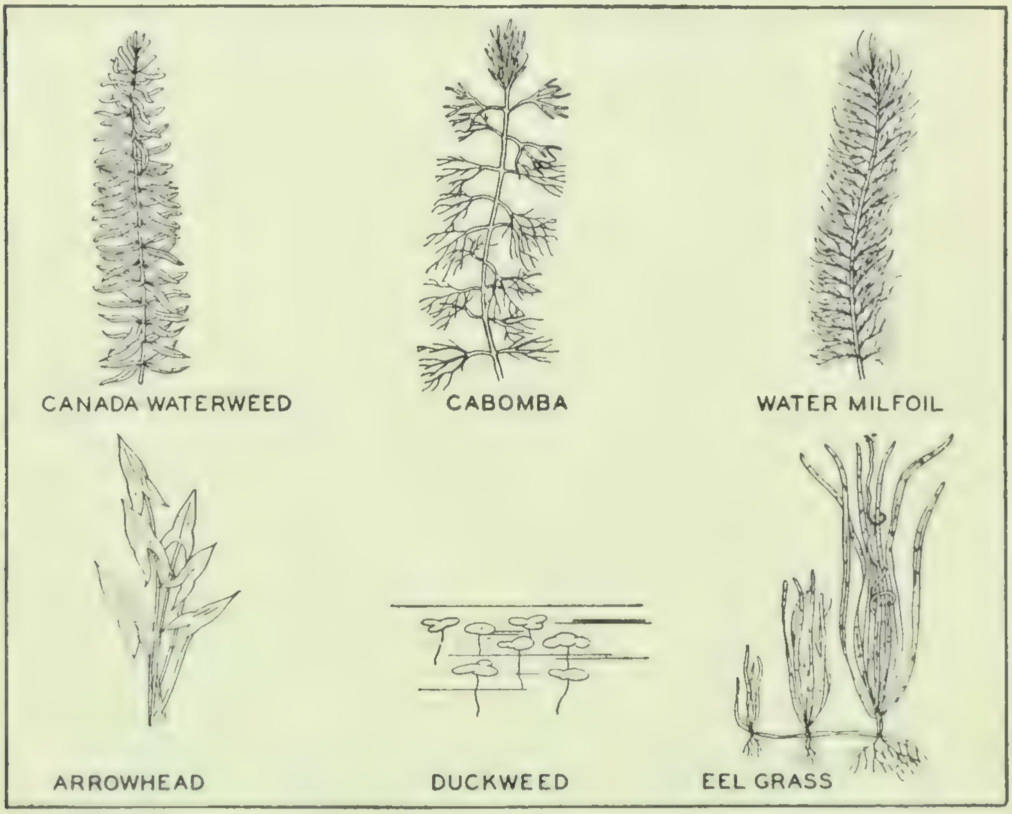


Fig. 113. Some plants which are suitable for an aquarium.

It is unwise to introduce animals until the plants resume their growth. This may require three or four days. The following are interesting animals for an aquarium: minnows, tadpoles, crayfish, water-beetles, dragonfly nymphs, caddis-fly larvae, clams and aquatic snails. A baby turtle may also be included. It is usually recommended that predatory forms, e.g. the crayfish and beetle, be kept separate from the others. A difficulty the writer has experienced is that sometimes the crayfish disarranges the plants and tears them in pieces.

One should be careful not to overstock the aquarium. A rule frequently given is 'an inch of fish to a gallon of water'. This allowance may be slightly exceeded when experience is gained, but large fish should never be included.

Feeding of animals.

Injudicious feeding is one of the chief causes of trouble. Two or three packets of fish food should last half a dozen minnows for a year. About three times a week, morsels of meat should be given to the crayfish and beetles. Snails and tadpoles eat the green growth on the glass. Food uneaten after an hour should be removed. A piece of tubing a quarter of an inch in diameter and about fifteen inches in length is extremely useful in removing uneaten food from the bottom of the tank. A finger is held tightly over an end, and the other end is placed close to the food or other unwanted substance. When the finger is removed for a moment, the water rushes into the tube carrying the refuse with it. The end is again closed, and the glass tube with its contents removed from the aquarium.

Dead animals should be promptly taken out, unless they are being devoured.

The interdependence of water plants and water animals.

Frequently we speak of a *balanced* aquarium. This description is applied when the animals and plants are present in such proportions that dissolved oxygen derived from photosynthesis, along with that dissolved at the surface, is sufficient to supply what is needed for the respiration of both plants and animals; and, furthermore, when the carbon dioxide which dissolves at the surface, and that which enters the water as a result of respiration, supplies the plants with an amount sufficient for photosynthesis, (Fig. 114).

The plants provide some of the animals with food. For instance, the green algal growth gives nourishment to tadpoles and snails. From the excretions of the animals some mineral salts are obtained by the plants.

Needless to say, this interdependence is not confined to the aquarium. In large bodies of water there is the same interchange of gases. Minute animals (and also some large ones) eat the microscopic plants of the plankton. These animals are food for larger ones, which, in turn, are food for others still larger.

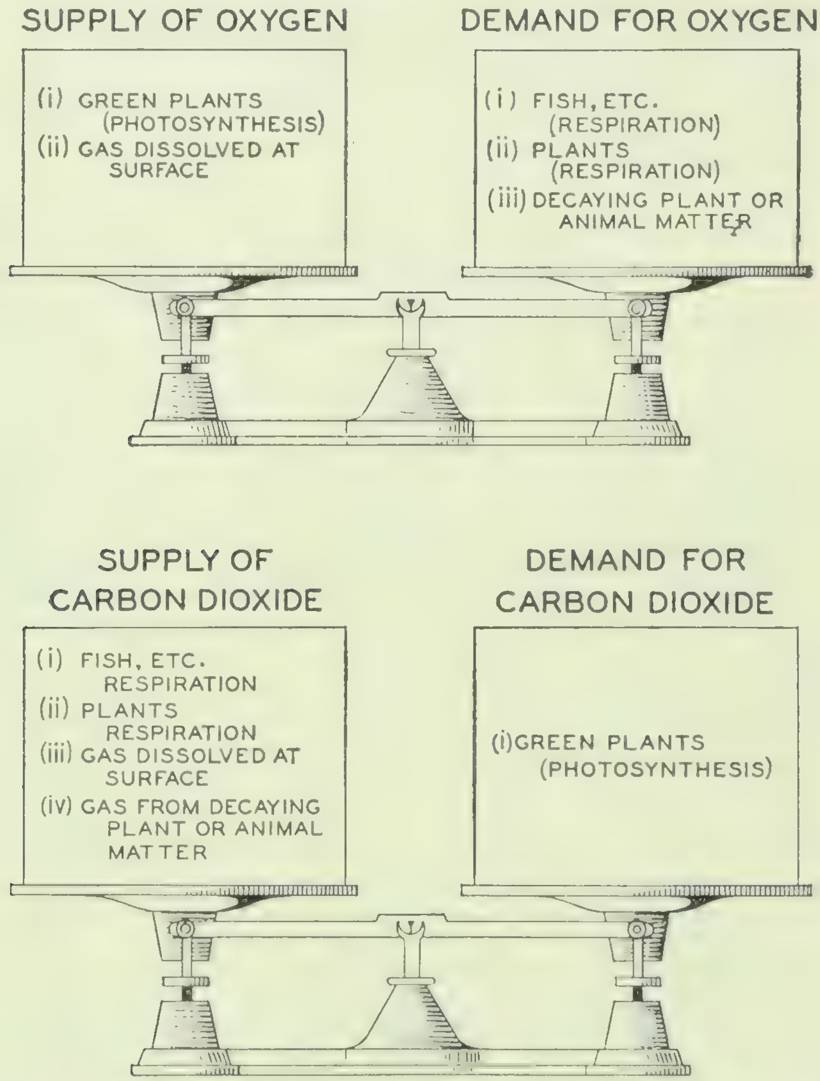
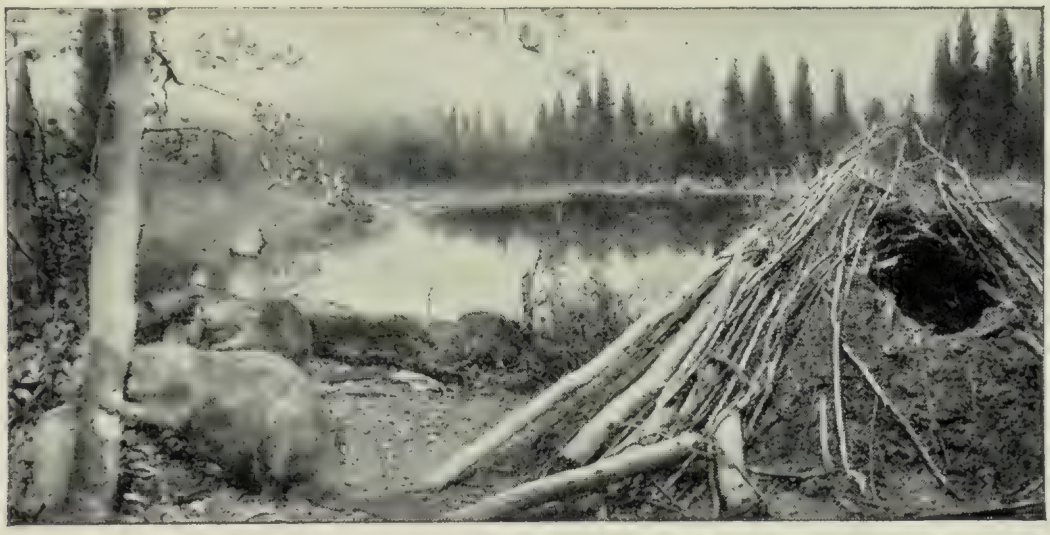

SUPPLY OF OXYGEN
(i) GREEN PLANTS (PHOTOSYNTHESIS)
(ii) GAS DISSOLVED AT SURFACE
DEMAND FOR OXYGEN
(i) FISH, ETC. (RESPIRATION)
(ii) PLANTS (RESPIRATION)
(iii) DECAYING PLANT OR ANIMAL MATTER
SUPPLY OF CARBON DIOXIDE
(i) FISH, ETC. RESPIRATION
(ii) PLANTS RESPIRATION
(iii) GAS DISSOLVED AT SURFACE
(iv) GAS FROM DECAYING PLANT OR ANIMAL MATTER
DEMAND FOR CARBON DIOXIDE
(i) GREEN PLANTS (PHOTOSYNTHESIS)

Fig. 114. The supply of, and demand for, oxygen and carbon dioxide in a balanced aquarium.

PROBLEM IV: How has the balance of nature in America been disturbed by the white man?

Before the white man came to North America, plants and animals had lived together for ages with very little interference from the sparse population of Indians. Those forms of vegetation best suited to conditions in the different regions were found. There were as many plant-eaters existing as the vegetation would support and their enemies would permit. There were as many flesh-eaters as the plant-eaters could sustain. A balance, which was by no means perfect, prevailed. From time to time the balance would be upset by unusual weather conditions or by disease among the animals, but in the course of time a new balance was established.

Then the white man hewed down the vast forests and replaced much of the native vegetation with imported plants. With these food plants came weeds. Our fields are infested with plant-thieves the seeds of which were brought originally from Europe in impure crop seeds, in ballast and on clothing. Birds and mammals whose homes vanished with the forests became scarce. In some cases, however, their places were taken by other animals. The hare retreats northward as the forests disappear but the cottontail rabbits and birds of the open spaces, like the meadowlark, blue bird and bobolink, extend their range as clearings are made. Swamps in which countless wild duck once found their food were drained. To-day, large numbers of former streams exist only in spring,



(American Museum of Nat. Hist.)

Fig. 115. Man has almost exterminated the beaver in North America.

or are quite dried up because of the removal of trees and the drainage of marshy ground. As a result, aquatic life has suffered. For one reason or another, certain animals were nearly wiped out. The beaver is no longer found in much of its former range, and of the fifty million buffalo of the plains relatively few remain. Many harmful animals were introduced. Among the insect pests which have found a new home are the imported cabbage butterfly, the European corn borer, the warble fly and the spruce sawfly. By providing potato plots from the Pacific to the Atlantic oceans, man has made it possible for the Colorado potato beetle to spread across the continent from its former home in the western states. Brown rats and house mice have spread far and wide.

We may regret the disappearance or scarcity of some of the native plants and animals, but it could not be expected that in a land-hungry world a continent could be preserved as a wild life sanctuary. However, it is well for us to learn something of what has been called, the 'web of life', so that when we must interfere with nature we shall do so as thoughtfully as possible. This interference may, as we have indicated, consist in the removal of the original vegetation, the intentional or accidental introduction of new plants and animals, the killing of large numbers of the native animals or their complete destruction, the drainage of swamps and the changing of the character of the soil by cultivation. To these we may add the pollution of streams by waste materials from factories, and the building of towns and cities.

PROBLEM V: Has man always been wise in the ways in which he has interfered with natural conditions?

Some Australian experiences:

Later we shall tell you of the unfortunate bringing of the prickly pear to Australia, (p. 207). The story of the disastrous introduction of rabbits to Australia in 1864 is a familiar one. Money has been spent generously and man's skill used in vain; the plague remains. Probably the only bright spot in this experiment is apparent to the manufacturers of wire-netting, thousands of miles of which have been erected.

An Australian bird of the kingfisher group earned much dislike because of its annoying practice of shrieking. Destruction of the species seemed to be the remedy. As this goal was approached, a more serious problem presented itself for solution. Poisonous snakes became numerous, and caused many deaths among human beings and domestic animals. After an inquiry, which revealed that each bird killed thousands of snakes annually for both food and amusement, the fisher was protected.

From "Biology of Everyman" by Sir J. A. Thomson (Dent.)

Fig. 116. The prickly pear.

A lesson from Jamaica.

An animal called the mongoose preys upon rats. This merit seemed to warrant its importation from India to Jamaica, where extensive damage to sugar plantations was being caused by these pests. In the presence of so much food, the mongoose multiplied rapidly, and finally rats became very scarce. One problem was solved, but another was created. The mongoose turned its attention to substitutes for rats. Young pigs, lambs, pups, kittens, frogs, poultry and wild birds were

From "Nature Study and Agriculture" by Schmidt, pub. by. D. C. Heath.

Fig. 117. The common brown or domestic rat has pioneered with man in every quarter of the globe.

eaten. As the frogs, toads and birds diminished in numbers, insects increased. Fortunately, the mongoose itself was attacked by ticks, which weakened its vitality and reduced its rate of reproduction. Also, confronted with a decreased supply of the new food, it has started to eat insects.

A mistaken kindness.

Someone has said that a good set of enemies is a great benefit to any group of animals. If from the enemies we exclude man, who has almost perfected the art of killing, there is much to support the statement. The willow grouse of Norway has alternating periods of scarcity and abundance. During the latter, disease becomes rife and soon the numbers begin to dwindle. In an effort to prevent the return of lean years, Norwegian sportsmen began to exterminate the mammals and birds that prey upon the grouse. This action had an unexpected result; the birds became more liable to disease. The following explanation has been advanced. Birds which are diseased have a smaller chance of escape from enemies than those that are fit. Consequently, when birds of prey and mammals are plentiful, there is a continuous weeding out of sickly grouse. This helps to check the spread of the disease. A somewhat similar fluctuation of grouse in Ontario has been under investigation in recent years.

Introduced muskrats became a menace.

Shortly after the Great War, some muskrats were brought to England where they found conditions so suitable that they speedily became a nuisance. Vigorous measures for their destruction were undertaken.

Some years ago, about fifteen muskrats were brought to one of the islands in the Queen Charlotte group. Their numerous descendants have caused so much damage to sea-dykes and have displayed such a keen appetite for salmon fry, that serious doubts as to the wisdom of the importation have arisen.

The introduction of house sparrows and starlings to North America.

We look back wistfully on the failure of the first attempt in 1850 to introduce the house sparrow to the United States. Two years later, a hundred birds were brought in and some of these survived the winter. Encouraged by this partial success, the lovers of the little bird obtained more, which they distributed to a number of towns in Canada and the United States. For a time, the sparrow enjoyed the protection of the law, but after a rapid increase in numbers and continent-wide distribution, made possible in part by railway cars, its unpleasant habits became apparent to all. To-day, its numbers are probably stationary or even diminishing, because of the replacement of horses by automobiles, another disturbance of nature.

The introduction of the European starling to North America has had unforeseen consequences. In 1915, a dead starling was picked up in Halifax, the first recorded appearance in Nova Scotia. It was not until 1922 that the bird was observed in Ottawa. In 1931, a record was obtained from York Factory on the west coast of Hudson Bay. The first recorded appearance in Alberta was in 1934. In Europe, the starling is regarded as a beneficial bird, or at worst, one which does not attract attention by being a nuisance. There is no marked change in numbers. Here it has increased with a rapidity truly amazing. Thousands of them gather in shade trees in cities and bother people who live in their neighbourhood. They remain in Canada during the winter and occupy the nesting places of more desirable birds before these return from the south. For good reason, they are regarded as a pest in fruit-growing areas.

An example of the disturbance of the balance of nature by cultivation.

Under natural conditions, the pale western cutworm, the most destructive insect belonging to this family in Canada, lived on the surface of the soil. There it was exposed to the attacks of certain other insects which held its number in check. When the prairies were put under cultivation, the loosened condition of the soil made it possible for the larva to burrow into the ground. In this protected situation the dangers of living were greatly reduced, and as a result the pest multiplied rapidly. It may be added that rainfall brings this cutworm to the surface where it remains until the soil becomes dry again. During this period, it is exposed to its natural enemies. The histories of this cutworm and the potato beetle give us examples of how cultivation has upset the system of checks which are imposed on certain insects under the original natural conditions.

Why there is risk in introducing new species.

The introduction of undomesticated animals to a country is frequently risky. Those species that can survive under the new climatic conditions are removed from the parasites and larger enemies which in the original home were effective in keeping their numbers within bounds. As a result, the mammal, bird or insect which played a relatively minor rôle in its native land, often becomes a serious pest in its adopted home.

The introduction of parasitic insects.

In the case of introduced injurious insects, the scientists frequently seek for the parasitic or other insects which preyed upon them in their original home. A scale insect from Australia caused severe loss to the citrus fruit industry in California until it was successfully fought by a ladybird beetle purposely imported from the same continent. Tiny wasps which lay their eggs in the corn-borer larva have been brought from Europe to North America. Parasites of the spruce sawfly have also been imported. Not infrequently, parasites have their own parasites and it is important that these be left behind.

Exercises:

(1) Explain how the balance of nature is upset by the destruction of hawks and owls.

(2) An interesting example of the interdependence of plants and animals was noticed many years ago in England. Where there are many cats there are few meadow mice. Meadow mice de-

stroy the nests of bumble-bees. Hence, the fewer the meadow mice the greater is the number of bumble-bees. If bumble-bees are numerous, many red clover flowers are visited by these insects. Therefore, the more cats there are, the greater is the production of red clover seed.

Try to find links between plants and plants, between animals and animals, and between plants and animals.

Can you name an insect that feeds on another?

(3) Read the accompanying article clipped from a newspaper. Make a list of similar practices carried out in Canada.

MOTH *VERSUS* PRICKLY PEAR

"Set a thief to catch a thief," is a motto frequently used by modern scientists in dealing with the pests that afflict plant and animal life. Australia has just given an illustration of this procedure. The prickly pear had overrun millions of acres of land. A South American moth, having the name *Cactablastis cactorum*, was deliberately introduced into Australia to war upon the prickly pear. The grubs attack it greedily and the destruction is enormous. 'Already there are prosperous dairy farms where a few years ago there was a wilderness of prickly pear.'

ENRICHMENT SECTION, NUMBER 7.

The Dominion parasite laboratory at Belleville, Ontario.

In this laboratory are bred millions of insect parasites which feed on the eggs of the sawfly. These parasites were imported into Canada from Europe, where it was known they kept the European spruce fairly free from the sawfly pest. During the last few years they have been bred on a large scale at Belleville, Ontario, and set free in different parts of Canada with good results.

This laboratory is sending hordes of praying mantises to the western provinces to feed on grasshoppers and put an end to their scourging of the plains. In a small way, they have bred the insect in the laboratory, but breeding it in this fashion is an expensive business, so the scientists collect hordes of the mantises around Belleville, Picton, and Trenton, where they are plentiful. They are then shipped by the hundreds to the west.

Exercises:

1. Learn as much as you can about the work done at this laboratory at Belleville.

2. Name some parasites that assist man in his fight against harmful insects.
4. How is the Canadian border guarded against insect invasion? (Hint: All nursery stock imported into Canada from the country must be routed through one of ten ports for inspection.)

C. **MINOR STUDY**: There is a definite relationship between the number of young produced and the parental care of animals.

PROBLEM I: How do various animals take care of their young?

When that single-celled animal, the amoeba, atttains a certain size, it divides into two amoebae, each suitably equipped for its mode of living.

No parent remains on which the animal can be dependent. Indeed, it may be said that the small amoeba is better fitted for living than the parent, for by division, the surface area per unit of volume has increased, and the whole surface is, so to speak, the mouth of the animal. Between this independence

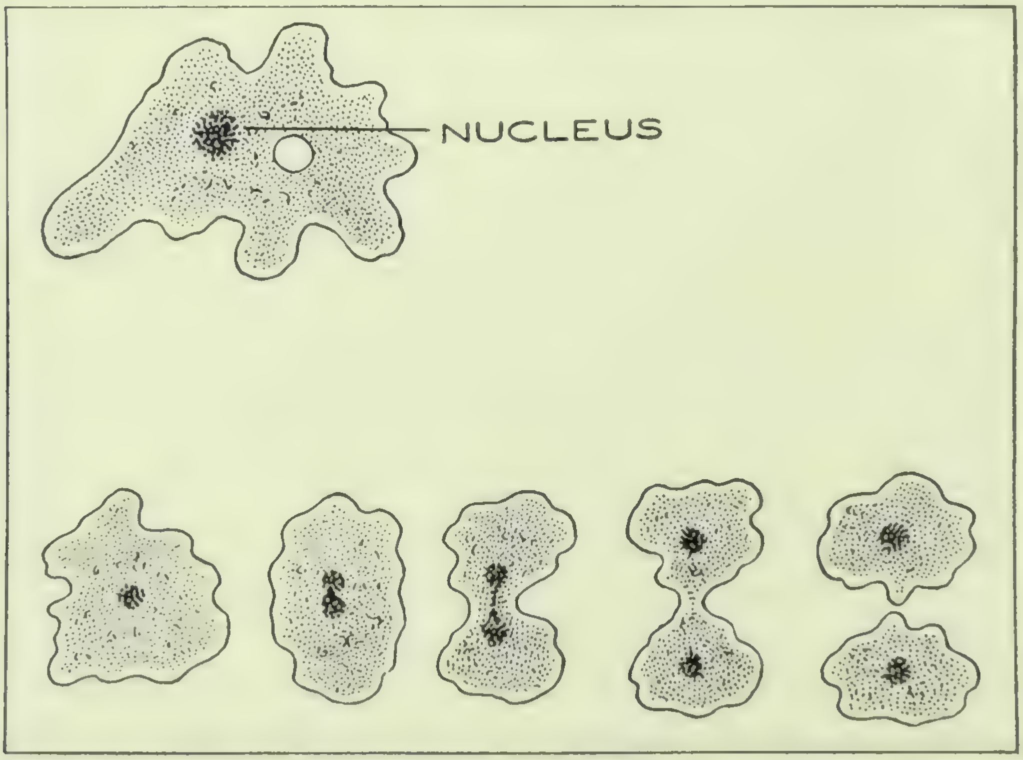
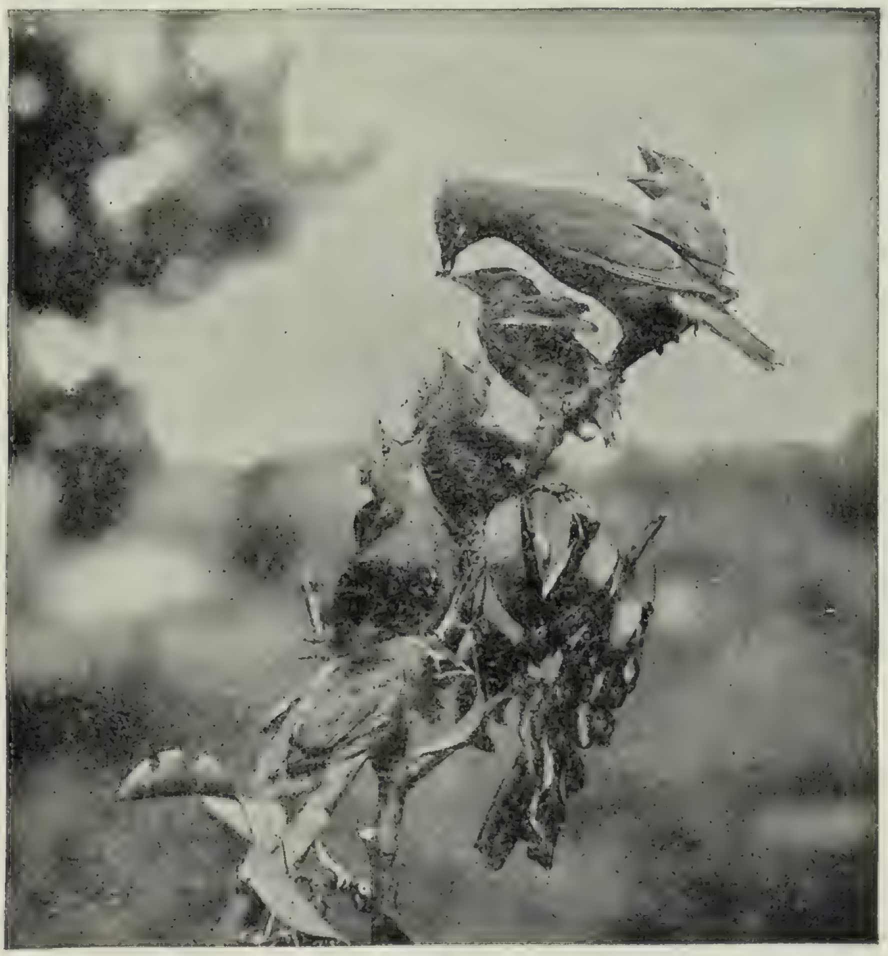


Fig. 118. The amoeba is a one-celled animal. When it attains a certain size it divides, forming two 'daughter' amoebae.

of the young of the simpler animals and the almost complete helplessness in infancy of many higher forms, there is a wide range.

Mammals.

The young of mammals are nourished during gestation by the blood stream of the mother. After birth they receive milk, described as the 'perfect food'. Some, like the foal and lamb, are able to move about in a relatively short time. Others, such as pups, kittens, young mice, and rats, are much less able to fend for themselves. These weakly young are born in well-hidden places, and kept there for a time unless, of course, they are born in a stable or a house. The female rabbit prepares a comfortable nest and lines it with portions of her own



(*Nat. Assoc. of Audubon Societies.*)

Fig. 119. A cedar waxwing and her family.

fur. Mother cats are said to instruct their young in the art of killing mice. One cat was accustomed to being fed at fixed times. While her kittens were still small, she carried them by the nape of the neck at the appointed hour to receive their share. Later, she pushed them, one by one, over the two hundred yards which separated her nest from the house.

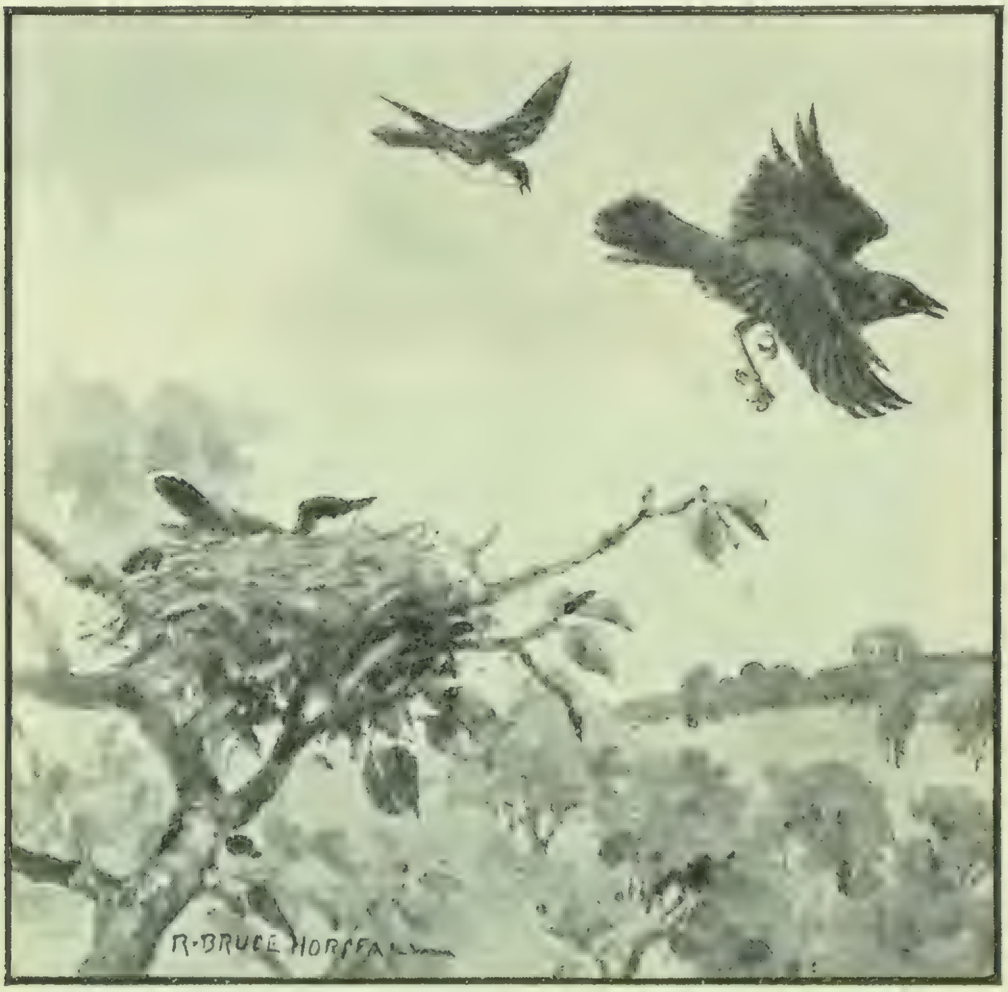


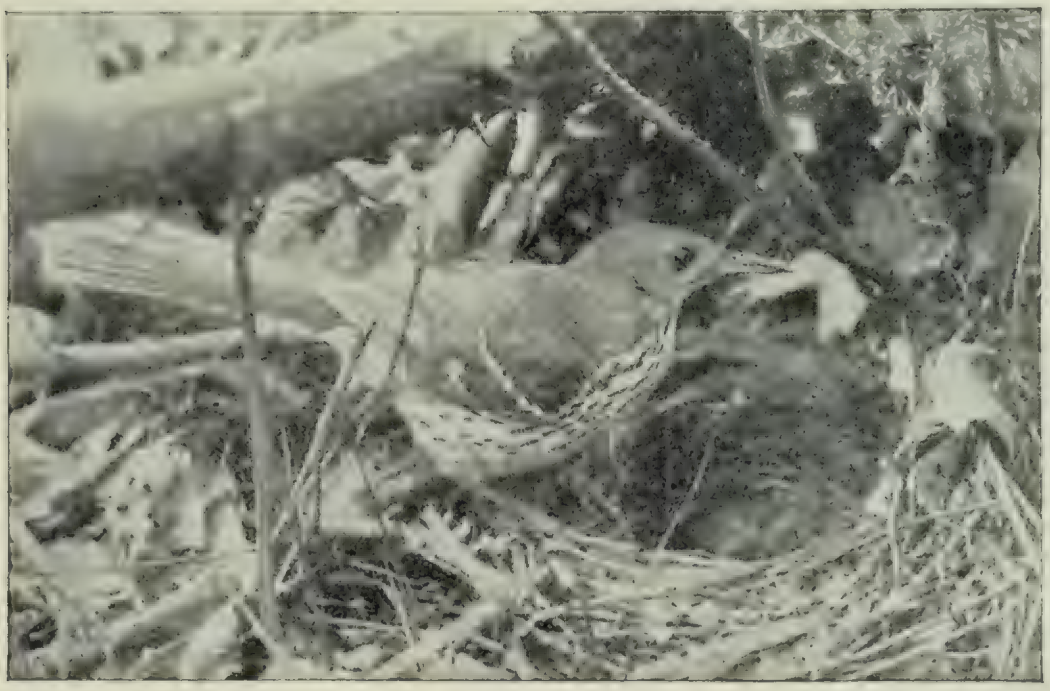
Fig. 120. The kingbird is one of the flycatchers. You may often see him putting a crow to flight.

The kangaroo bring forth their young in a condition which, in the case of other animals, would be termed premature—those of the largest kangaroos are about the size of one's little finger. For a time these very helpless little ones are carried in a pouch and nourished by the mother.

We are all familiar with the courage with which the mammal mother defends her offspring and her distress if deprived of them.

Birds.

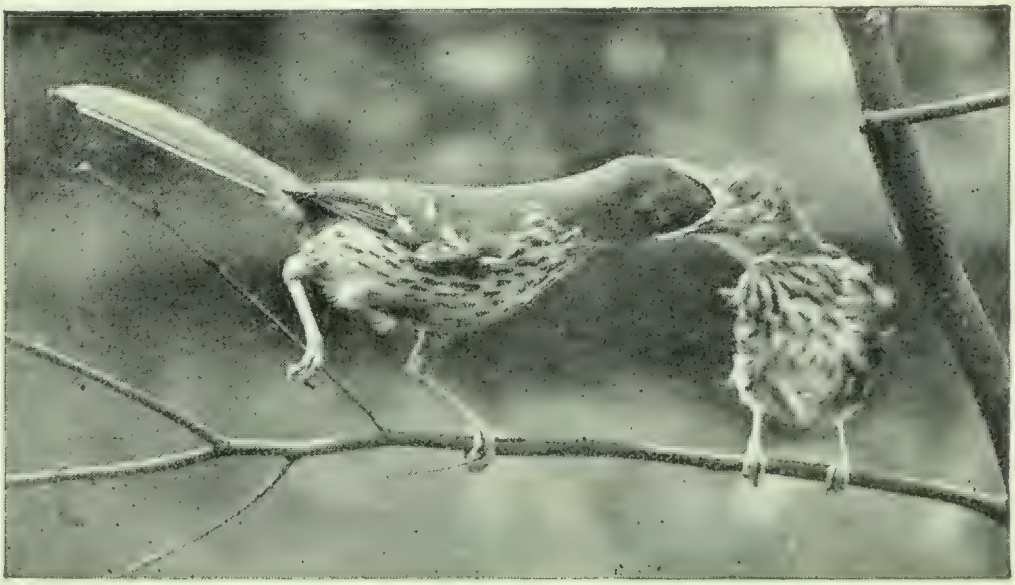
Generally speaking, birds are good parents. In the construction of the nest, which is often well concealed or more or less inaccessible to enemies, both male and female frequently co-operate. Some birds, for instance the guillemot, a sea bird, lay their eggs in exposed places, often on rocky ledges. These eggs are so shaped that when disturbed they roll in circles and thus escape the fate of Humpty Dumpty. Eggs laid amid pebbles and stones are usually coloured so as to harmonize with their surroundings.



(*Nature Magazine.*)

Fig. 121. Brown thrasher and young. Note the protective coloration.

Incubation is mainly the work of the female, whose somewhat drab plumage helps to conceal her, but in a few instances the male takes full responsibility. There is an interesting reversal of the customary domestic arrangement in the Phalaropes, a group of shore birds. The brightly-coloured female pays court; the demure male broods on the eggs. In a number of cases, for instance the pigeons, both parents take turns. As a general rule the male remains close by. He may defend the nest and often he brings food to his mate. If we approach the nest of a plover, the mother flies quietly away and, at some distance from her nest, behaves as though her wing were broken. By this ruse, she withdraws attention from the vicinity of her nest. The penguins make no nest, but balance the egg on their webbed feet, and in this way keep it warm and off the ground the whole five weeks of its hatching. The egg is rolled from the feet of the female to the feet of the male about every three days when the female gets hungry.



(L. W. Brownell.)

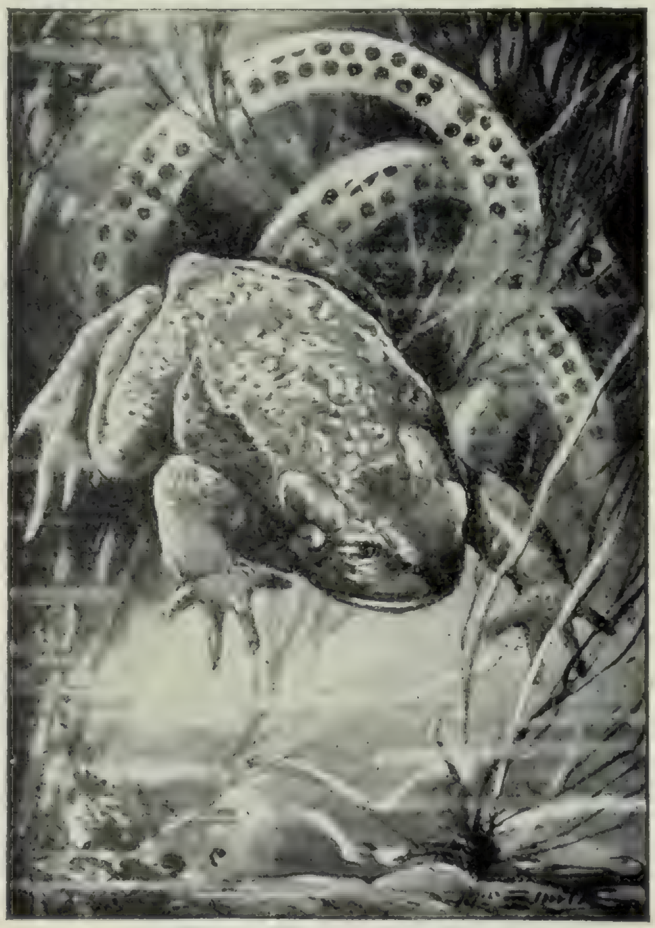
Fig. 122. The baby thrasher has no need of a bib.

Young birds receive food before they leave the shell. This food consists of yolk. The practice of withholding food from newly-hatched chicks insures that the last of the yolk will be absorbed and early digestive trouble avoided. To provide their rapidly developing young with proper and sufficient food makes much labour for the parents. One observer reports that fully 400 cutworms a day were brought by a pair of prairie horned larks to their charges. On the average, food was brought every two minutes. A pair of house wrens carried insects to their nest forty to sixty times an hour. Pigeons give their nestlings a food called 'pigeon milk' supplied from the crop. It has been suggested that the bright colour of the young bird's gaping mouth is a guide to the parent engaged in giving food.

Thus, with building and cleaning the nest, with incubating the eggs, feeding and defending the young, most birds are busily occupied during the breeding season. The shirking of parental duties by the cowbird and the magpie is in strong contrast with the care of the others.

Other Vertebrates (Animals possessing backbones).

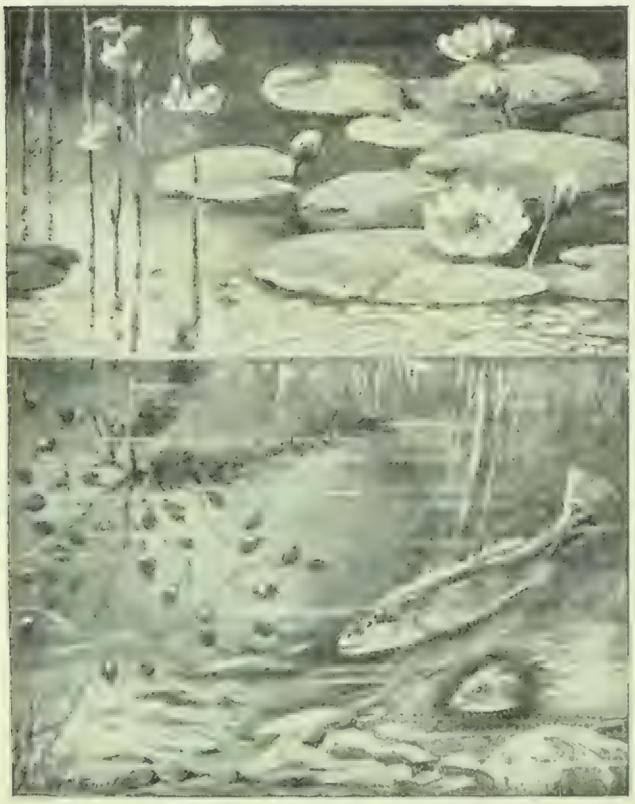
Care for the young is not as common among other backboned animals as it is among mammals and birds. Frogs and toads deposit their eggs in water and give no attention either to them or to the resulting tadpoles. There are a few exceptions. A male frog of the Chilean forest carries the eggs in his vocal sac. In this strange nursery the tadpoles complete their life-cycle. As young frogs they leave the 'parental roof' by escaping from the mouth of their father.



From "Biology for Everyman" by Sir J. A. Thomson (Dent).

Fig. 123. A toad and its spawn.

Relatively few fish display any sense of parental responsibility. Hundreds of thousands, even millions of eggs may be released in the water and from only a very small fraction of one percent of these come fish which gain maturity. We may take the codfish as a type which produces many eggs in order that a few may survive. At the other extreme is the stickleback, a dark-coloured little fish with a spiny back fin and a fighting nature. He builds a nest from aquatic vegetation into which he coaxes or drives a succession of females. These lay their eggs and depart, but the little father remains on guard until the young hatch out. Male sunfish also protect the eggs deposited by their mates in a rude nest. Both stickleback and sunfish lay relatively few eggs; the numbers are approximately 250 and 5,000 respectively.

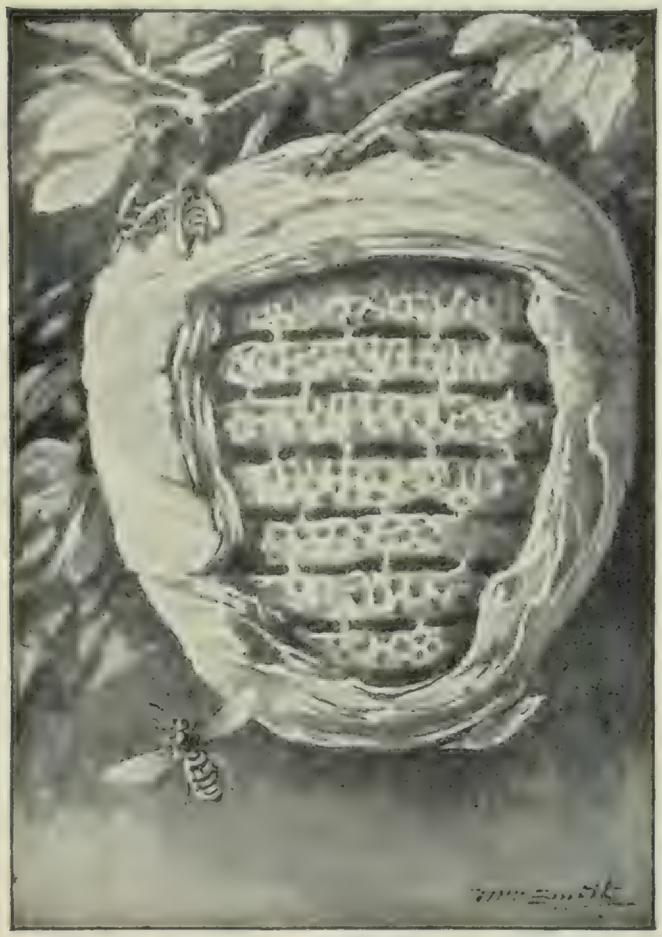


From "Biology for Everyman" by Sir J. A. Thomson (Dent).

Fig. 124. A stickleback and its nest.

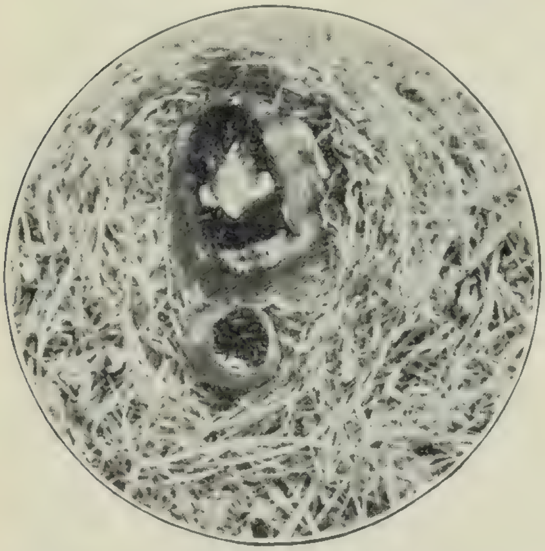
Insects.

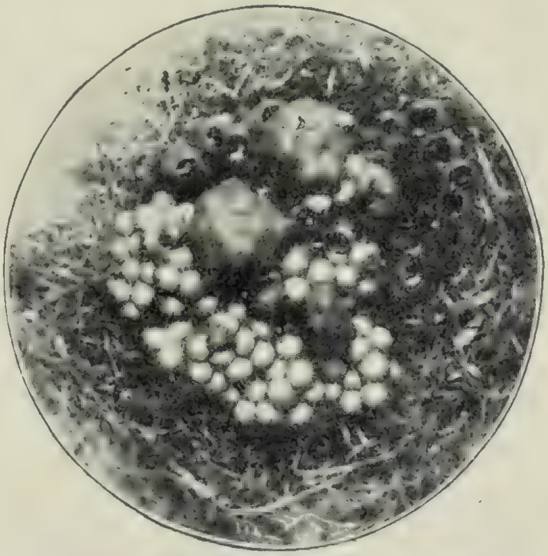
It would be easy to multiply examples of parental provision among insects. There are, for example, numerous cases in which the female seeks out and lays her eggs upon those plants, animals, or dead organic matter which the larvae must eat or die. We do not find European corn borers on potatoes, milkweed butterfly caterpillars on onions, or warbles in cats. There are the parasitic insects, such as those which attack the tent caterpillar. Many of these deposit their eggs in the larvae thereby providing their offspring with food. Certain wasps paralyze caterpillars, adult insects, or spiders, and carry them to their nests. After laying an egg on her victim, the wasp seals the cell. When the larva emerges it finds itself with fresh food ample for its needs. Should the paralyzed insect or spider die, its body remains in suitable condition for the fluid injected by the stinging mother acts as a preservative. Young adult honey bees act as nurses to the grubs or larvae of their kind and give them food. No one who has ever disturbed an ants' nest can have failed to notice the manner in which the workers seize the pupae and try to remove them to a place of safety.


From "Biology for Everyman" by Sir J. A. Thomson (Dent).
Fig. 125. Wasps' nest.

Observation of living ants in the classroom.

You will enjoy watching the activities of ants in your


(Courtesy Bee Div. Dom. Dept. Agr.)
Fig. 126. Brooding bumble-bee. Notice the nectar glistening in the honey-pot.


(Courtesy Bee Div. Dom. Dept. Agr.)
Fig. 127. Nest of bumble-bee. The white structures are groups of cocoons. Find the honey-pots.

classroom. A home such as that shown in Fig. 128 is a very convenient one to use. The width of the container should be an inch or less; the other measurements are unimportant. The soil should not be allowed to dry out completely.

Honey- or sugar-solution and dead insects should be given as food; a little sponge or a piece of blotting-paper should be kept soaked with water.

When the ants are not under observation, the glass walls should be covered with a black cloth or a piece of cardboard.

The ants and the soil may be brought indoors in a sealer or other convenient closed container. About sixty workers with eggs, larvae and pupae will be sufficient. If possible, the queen, who is distinguished by her size, should be included. Sometimes, the beginner tries to preserve the original tunnels of the ant-hills. Even if this were possible, it would be unnecessary; new tunnels will be constructed by the industrious little insects.

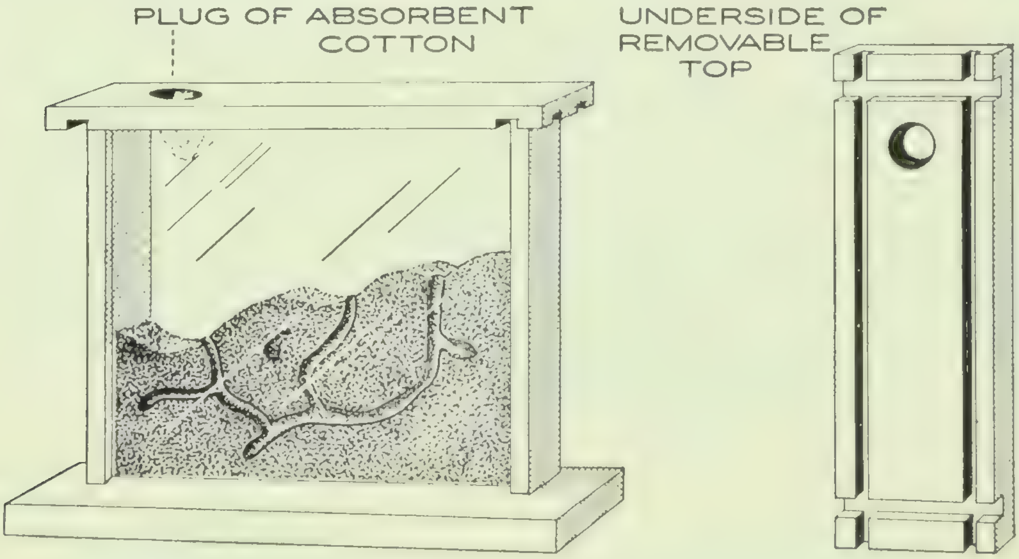


Fig. 128. You will enjoy watching the activities of ants.

D. MINOR STUDY: Animals are able to meet environmental changes of heat and cold.

PROBLEM I: How do some animals adapt themselves to winter conditions?

In winter the temperature falls below that point so important to plants and animals, the freezing point of water. This liquid to a very considerable extent enters into the composition of living things and is the home of many plant and animal forms. While the ground is frozen, water is no more available to plant roots than in the most arid desert. Dwellers in the soil, like earthworms and certain larvae, are unable to move about and obtain their food in the solid layer. Grass and other low-growing vegetation are not available to wild animals desiring them for food. Tree leaves, which during the summer fed great insect populations, have withered and fallen. Birds in whose diets insects were an important item, find their food greatly lessened by the first frosts. The two-fold winter hazard of low temperatures and scanty food supply is met by animals in a number of interesting ways.

How is body temperature affected by heat and cold?

No matter how warm or how cold the weather may be, the body temperature of healthy human beings is maintained at about 98.6° F. This temperature is produced by a kind of slow burning in our bodies, the resulting loss being made good by food. If our temperature is considerably above that of the surroundings—on a cold day we may have a temperature 120 Fahrenheit degrees above that of the air—more tissue is consumed and more food needed. Again, the more active we are the greater is the quantity of nourishment required for energy. In order that the amount of food taken may be a minimum, it is clear that movement should be reduced to the least possible, and that the difference between internal and external temperatures should be as small as possible.

What is meant by hibernation?

Roughly speaking, this is the plan adopted by certain animals. The animal retires into a burrow or other shelter in autumn and remains quite motionless. There is even a reduction in the rate of heart beat. Less tissue is consumed than when the animal is active; consequently, less oxygen is used and less carbon dioxide set free. There is also a fall in the body temperature which is very marked in the case of bats. Most animals which winter in this condition have a store of body fat when they enter the dormant stage at the beginning of winter. By the time they emerge in spring this fat is used up and the animal presents a more or less starved appearance. This way of passing the winter is called "hibernation". It is resorted to by the woodchuck or groundhog, the chipmunk, the skunk, the raccoon, the jumping mouse, and some bats, including the common brown one. The chipmunk does not become fat before it hibernates, but stores in its nest a supply of food. Occasionally during the winter the animal wakens and eats. If the weather is mild, and food can be obtained, the bear does not hibernate.

The hair or fur of mammals becomes longer and thicker in winter, a change which we may compare with our custom of putting on heavier clothing in cold weather. It is true that birds acquire new plumage in the late summer or autumn; but, since migratory birds moult, as well as winter residents, we must be cautious about describing the process as a preparation for winter.

Do some animals store food?

In autumn, nuts are collected and hidden in the ground by squirrels. Often the little animal forgets about his hoard or is killed before he can make use of it. As a result, he is often an agent in the spread of certain trees. The storage of food by the honey-bee is, of course, the basis of the honey industry.

What advantage is there in a change of colour?

The weasel and the snow-shoe rabbit, the one predatory, the other preyed upon, do not remain in shelters during winter, but continue the search for food. Their coats are brownish in colour during the summer, but in winter they become white. The advantage of this is clear. It is a curious fact that a little of the original colour is retained by each in winter, by the weasel on the end of his tail, and by the hare on the tip of his ears. Other Canadian mammals whose coats turn white in winter are the arctic hare and some species of lemming.

How do snakes winter?

Dormancy is not confined to mammals. Snakes seek an opening in a rock or a cavity under a tree and in groups of two or more spend the winter in a motionless condition. Their respiration is reduced, and the body fat stored during the summer is slowly consumed.

How do toads and frogs winter?

Toads burrow into the ground by means of their hind feet. Their plumpness when they emerge in spring is probably due to the absorption of water from the soil. Frogs winter in the mud of ponds and breathe through their damp skin. Since they cannot live under dry conditions, it is as necessary for them to avoid the drying winds of winter as the low temperature. It is only partly true that frogs can survive after being frozen. If the temperature of the frog falls more than a few degrees below the freezing point, the heart is frozen and the animal dies. A frog kept at ordinary room temperature does not hibernate. It may be mentioned in passing that snakes, toads, frogs, fish and insects are cold-blooded animals, that is to say their temperature is only slightly above that of their environment and changes as the temperature of the environment changes.

How does the land-snail winter?

Another animal which becomes inactive in winter is the land-snail. It crawls into a sheltered place and forms a partition across the opening of the shell. Certain kinds of snails make as many as six of these with intervening air-spaces. Man is not the only living creature to appreciate the value of double doors and the insulating quality of air. Tiny breathing pores are left in the partitions. The heart beats more slowly, less energy is used and hence a smaller amount of stored food is required.

How do insects winter?

Insects show as much difference in their way of wintering as they do in other respects. Some, like the Colorado potato beetle, winter in the adult stage in a well sheltered place.

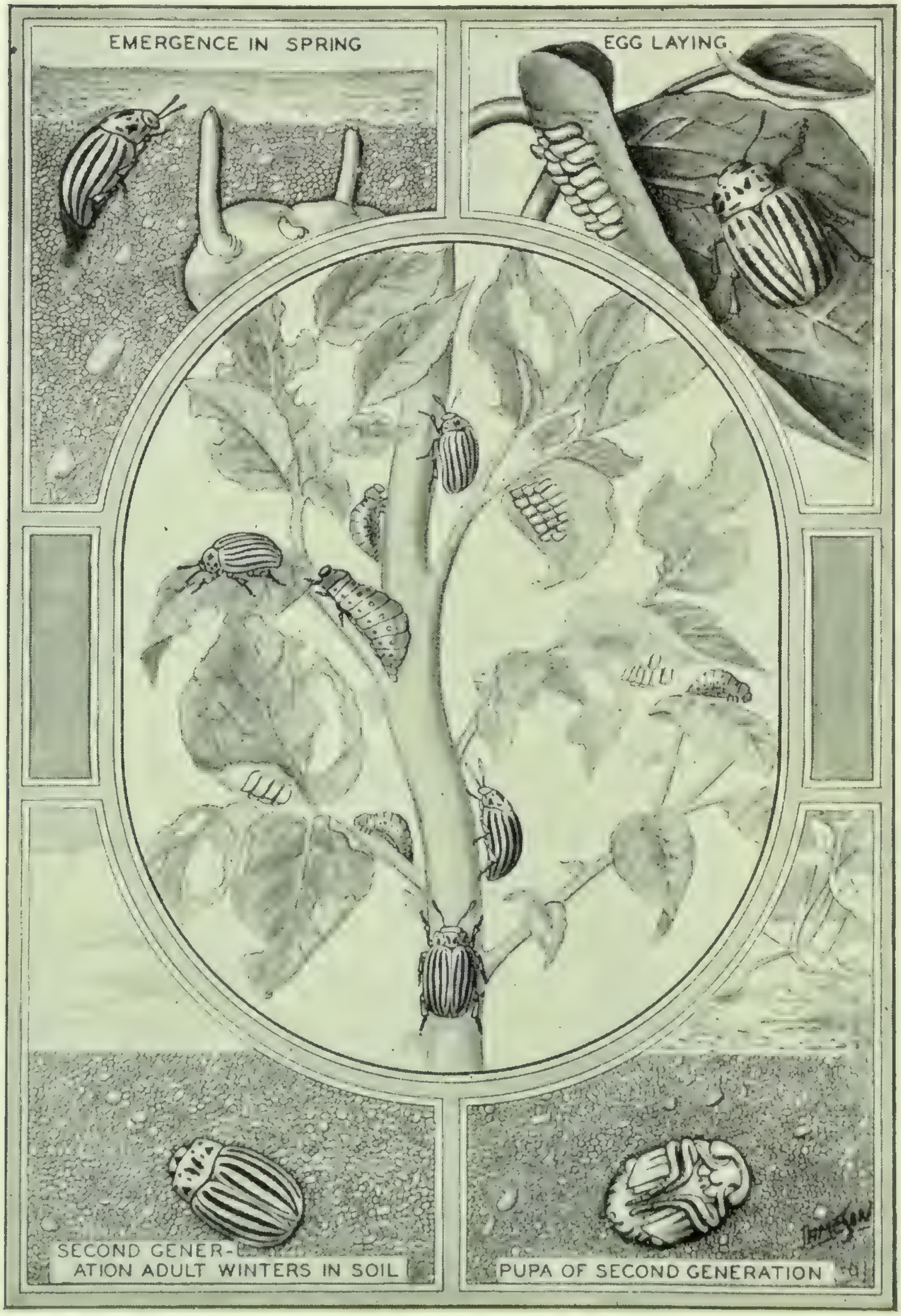

EMERGENCE IN SPRING
EGG LAYING
SECOND GENERATION ADULT WINTERS IN SOIL
PUPA OF SECOND GENERATION
JAMESON

Fig. 129. How the Colorado potato beetle spends its time.

Others, like the cabbage butterfly, spend the winter as pupae. The larva of the cabbage butterfly crawls into a sheltered place on a fence or building and then forms its chrysalis. Grasshoppers winter in the egg stage. Deposited in the soil these remain in cold storage until spring.

E. **MINOR STUDY:** **Animals are able to meet environmental changes in the food supply.**

Hibernating animals not only avoid extreme cold, but also, because of their inactivity, they are able to do without food.

We have referred to the storage of food by the chipmunk and to the fact that many animals accumulate a supply of fat on their bodies before the coming of winter.

Some animals migrate to places where food is plentiful. The reindeer travel to ice-free valleys in the summer. The caribou go south in winter and move north again in the spring. Most birds and other animals that live in high mountainous country go to lower levels during the winter season and to higher regions in summer. Bird migration is an interesting study. While we agree that the real reason for migration is lack of food, many factors still remain unsolved. Interesting experimental work on bird migration is being carried on at the University of Alberta by Dr. Rowan.

PROBLEM I: **Is there any evidence to bear out the following statements?**

1. The farther north a bird nests the farther south it winters.
2. With one exception, the cuckoo, it is the younger birds who have never made the journey that go first, leaving their parents to follow later.
3. The Timagami band of Ojibwas referred to the Milky Way as the "Birds' Path," in the belief that use was made of the stars as guides.
4. Birds use as their guides conspicuous landmarks like mountains and water-courses.
5. In the end it is customary to confess ignorance of how the bird find its way by attributing the ability to a mysterious "sense of direction".

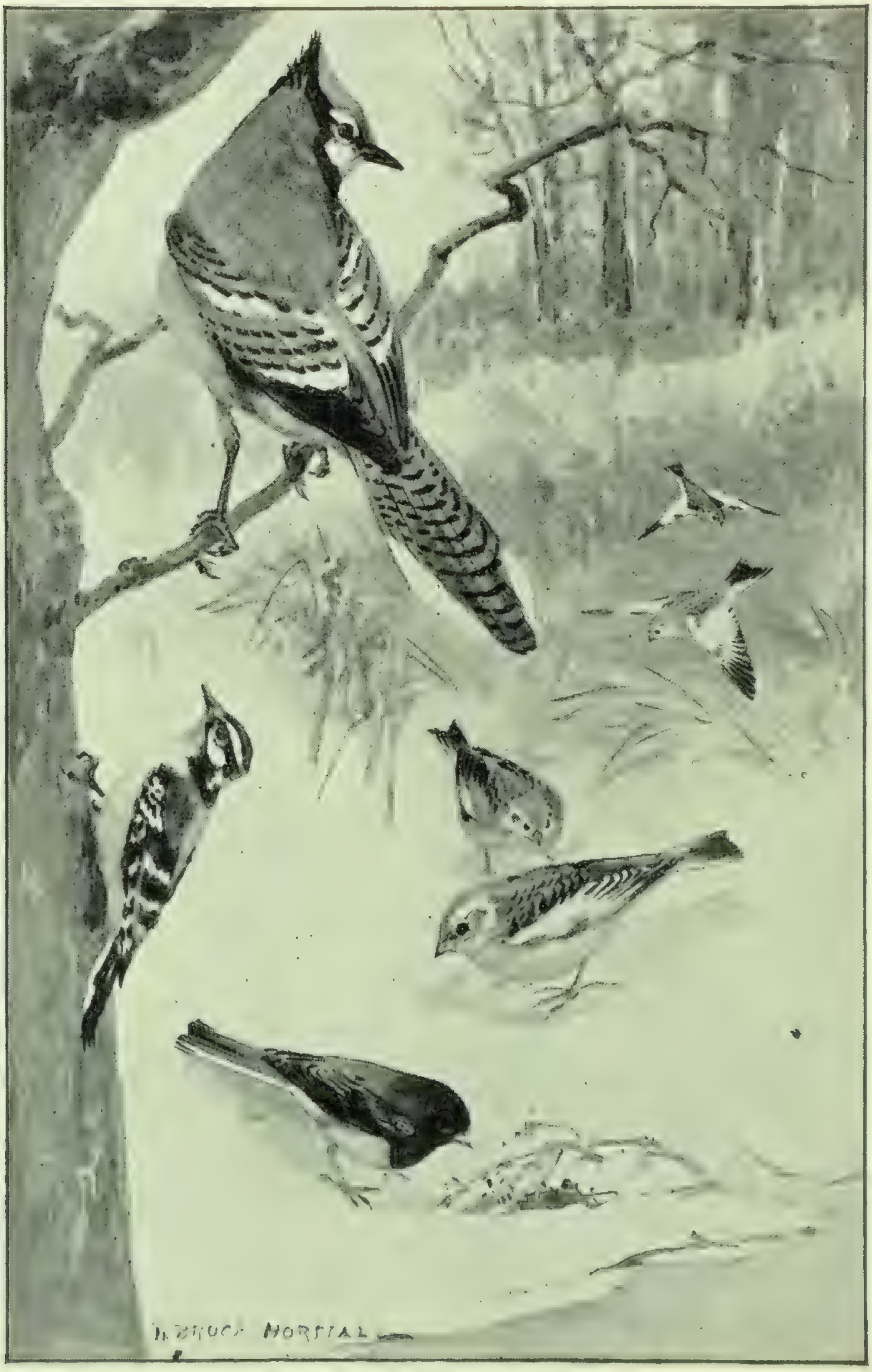


Fig. 130. Some winter birds.
On the tree are a bluejay and a downy woodpecker. On the ground, nearest the woodpecker, is a slate-coloured junco. The four remaining birds are snow buntings, sometimes called snowflakes. (In many parts, the junco migrates in autumn.)

The answers to these questions is being sought by scientists. There are some examples which are in accordance with the first statement. The arctic tern travels 11,000 miles from its summer home in North America to Antarctica where it remains through the northern winter. The golden plover nests in the Arctic and winters in South America and Hawaii. Do you know of any examples which contradict the first statement?

There is no doubt that many of the young birds leave for the south before their parents. For instance, the swallows usually rear two families on their visit to England. Before the summer is over, the first brood, unguided by the parents, fly to Africa, the winter home. Try to find out if the second statement is true of Canadian birds.

A study of existing migration routes does not give much support to statements three and four. All that we can say is that first, not last words are being spoken by scientists on this interesting topic.

PROBLEM II: Are there dangers in animal migration?

Thousands of land birds are forced down and drowned when attempting to cross large bodies of water. Many are killed in collision with obstacles such as telephone wires, cliffs, lighthouses, and buildings. Again, migratory birds may arrive at their summer home during a late spring. In such a case insect food is extremely scarce on account of the cold and many birds perish.

F. MINOR STUDY: Man has domesticated many mammals.

PROBLEM I: What features are possessed by all mammals?

The dog, the cat and their wild relatives possess a number of features in common. They have a coat of hair or fur; their young are born alive and for a time are nourished with milk provided by the mother. Scientists place these animals in a special class and give them the name *mammal*. Among the familiar mammals are the horse, cow, sheep, pig, mouse and bat. Mammals are regarded as the most highly developed and most intelligent of all animals.

We receive something of a shock when we learn that the whale is not a fish but a mammal. We object, and point out that the animal has the shape of a fish, that it is without legs, and has no hair. However, the young are born alive, the mother suckles her baby, and there are some hairs about the mouth of a young whale. It is true that there are only the traces of hind limbs and that the fore-limbs are represented by flippers. Whales have no gills like fish, so they must come to the surface to breathe.

Fig. 131. A whaling vessel in the old days of sailing ships.

Another strange animal included among the mammals is the duckbill of Australia. The young are hatched from eggs, but like other mammals, are at first fed on milk.

Exercises:

It has been said that mammals which have wet noses are 'the aristocrats of the smell world'. Compare the nose of the dog with that of the cat in this respect. Cite other examples in support or disproof of the assertion.

PROBLEM II: What mammals were most readily domesticated?

Certain mammals that live chiefly on vegetation have their feet provided with hoofs. They live together in herds and depend chiefly on massing or speed to protect themselves against enemies.

These hoofed animals were less dangerous to hunt than animals that eat flesh, hence they were more readily domesticated. They were easily herded together and driven from place to place. Besides providing food for man, they acted as beasts of burden for the transportation of goods and helped greatly in the cultivation of land. Many industries have grown up in Canada that are dependent on domesticated animals. Sheep, goats, camels and alpacas furnish fibres used in the world's clothing. Packing plants, shoe manufacturers, and many similar processors make ranching, dairy farming and mixed farming profitable occupations in western Canada.

G. MINOR STUDY: The most important domestic mammal.

PROBLEM I: What was the origin of cattle?

No cattle were found in the New World when the white man arrived. There were, it is true, numerous bison which are akin to the ox, but of these only protected herds exist to-day. Our present breeds of cattle in America and Europe are believed to be descended from wild oxen which formerly ranged over Europe. On a few of the large estates in Great Britain there are still herds of small wild white cattle which are regarded as relics of one of the ancestral breeds.

PROBLEM II: How did wild cattle protect themselves from enemies?

(i) What means of offence and defence were employed by the wild ox? What occasions arise to-day for the use of these weapons by domestic cattle? Of what use is the cow's tail to her?

(ii) Describe the manner in which cattle graze. Do they chew their food carefully while grazing? Do they graze continuously or intermittently? When is the cud chewed? How does a cow move her mouth when chewing the cud? Obtain the skull of a cow and examine the teeth; notice the places where teeth are lacking. Are there any canine teeth? For what purpose do the cheek teeth seem fitted?

(iii) Is the hoof of the cow whole or divided? From your observations suggest how the cow's hoof helps the animal when she is walking over marshy ground.

Our modern cattle lead very sheltered lives; seldom do they find it necessary to defend themselves from enemies larger than insects. However, from time to time we can make observations from which we may infer how wild oxen behaved when threatened by flesh-eating mammals.

Let us imagine a herd of wild oxen which has caught sight or scent of a pack of wolves. At first the cattle take refuge in flight for they are fairly swift of foot. The wolves are not shaken off and gradually gain on the herd. Then the cattle form a ring around the calves, and with lowered heads await their pitiless enemies. Most formidable of all is the fierce and muscular bull. We can picture the hungry wolves circling the wary herd, feinting, trying to break the ring. Some are caught on the horns and flung, others are trampled. The sequel we shall leave to the imagination of our readers.

The wild cattle came down to the valley and ate the juicy grass along the banks of streams. Their cloven hoofs and also the small toes or 'dew claws' helped to prevent them from sinking in swampy ground or in the river bed where the animals sought refuge from insects. After grazing rapidly for a time, the herd retired to a more secluded and safer place, perhaps in the forest, perhaps on a hill where a look-out could be maintained, and there gave itself over with supreme contentment to chewing the cud.

PROBLEM III: What are the greatest enemies of cattle to-day?

The greatest enemies of cattle to-day are not carnivorous mammals but the warble- and heel-flies. Larvae hatched from eggs deposited on the cow cut their way through the skin and enter the body. After a period of six to eight months, the larvae or warbles, as they are called, leave the cow through holes in the skin along the back. It is indeed unfortunate that the damage is done to the most valuable part of the cow's hide. When the flies are depositing their eggs, the irritated cattle roam about aimlessly with the result that they give less milk and fail to gain in weight. The total annual loss to farmers in Ontario alone due to these flies is estimated at more than five million dollars. To protect herself, the cow uses her tail. Also, she often enters streams where many of the larvae are smothered before they have time to make their way into her body. Fortunately, suitable methods of control have been devised, which, if put into general use, will reduce the losses greatly.

PROBLEM IV: **How has man improved cattle?**

Even before modern cattle breeding began, there must have been a gradual improvement in the type of animal. Those exceptional cows which were obviously profitable to their owners would be greatly prized and their offspring would be widely sought. However, the most rapid developments have taken place in less than two hundred years. Systematic selection was made of cattle which matured quickly and had a decided tendency to produce flesh. These were mated. Only those offspring which displayed the same desirable qualities were retained for breeding purposes. Thus a number of 'beef breeds' characterized by early maturity and tendency to fatten were developed. In the production of 'dairy breeds', selection was made from cattle which possessed, to an unusual degree, the abilities to give large quantities of good milk and to transmit this characteristic to their offspring. The exhibition of superior cattle shows organized by agricultural societies helps greatly to stimulate interest in the breeding of better-class stock. Very valuable aid has also been given by Departments of Agriculture, by breeders' associations, and by wealthy men whose stock farms were established as hobbies.

PROBLEM V: **What are the characteristics of beef cattle?**

Good beef cattle are low-set in appearance and have wide deep bodies which when viewed from the side are roughly rectangular. Since the more expensive cuts of meat are obtained from the upper part of the body and the hindquarters, these parts should show high development. If the ribs are long and well sprung, the animal is able to carry a considerable quantity of the higher priced meat. Furthermore, well-arched ribs show that the animal has a strong constitution. The loin should have ample breadth and depth. From the shoulder or chuck region relatively inexpensive meat is obtained, hence excessive weight in the front is not desired. A level back indicates sufficient strength to carry a large weight of flesh. Strong well-placed legs are a necessity.

In view of the Englishman's liking for roast beef we can understand why he has made the greatest contribution to the breeding of beef cattle. The record of Scottish breeds is also noteworthy. Each of the following popular beef breeds was developed in Great Britain.

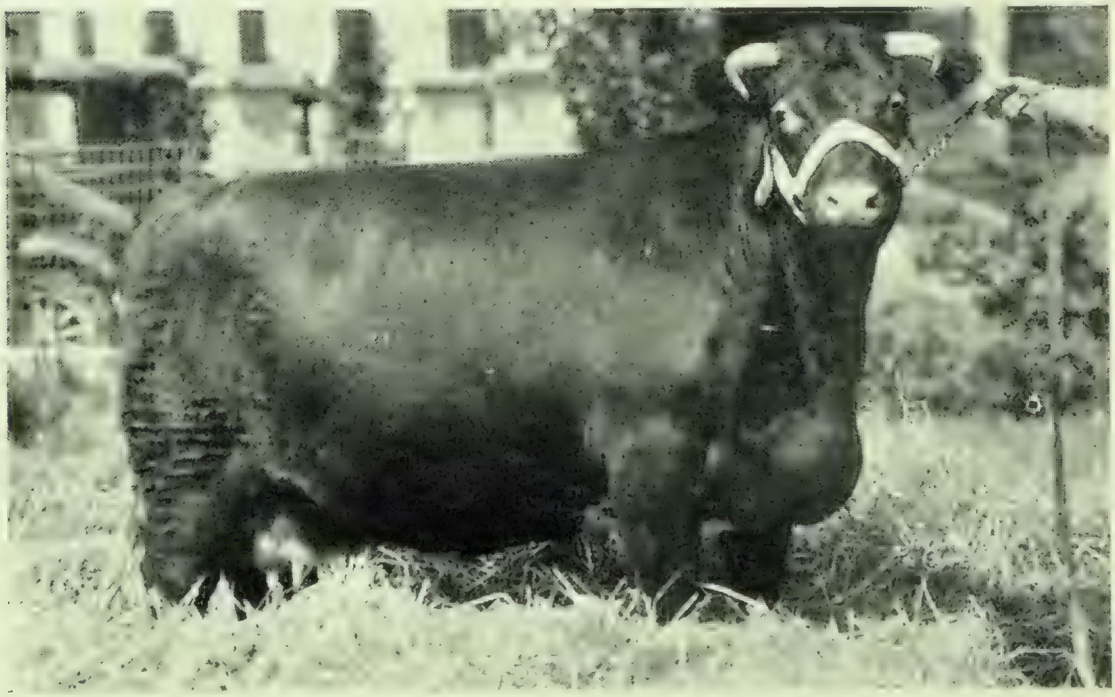


Fig. 132. Glenburn Clare 6th. Typical Shorthorn cow.

(a) *The Shorthorn.* The Shorthorn breed which originated in the counties of Durham and York in northern England enjoys great popularity in Canada and elsewhere. In colour the Shorthorn is generally roan, but red, red and white, and

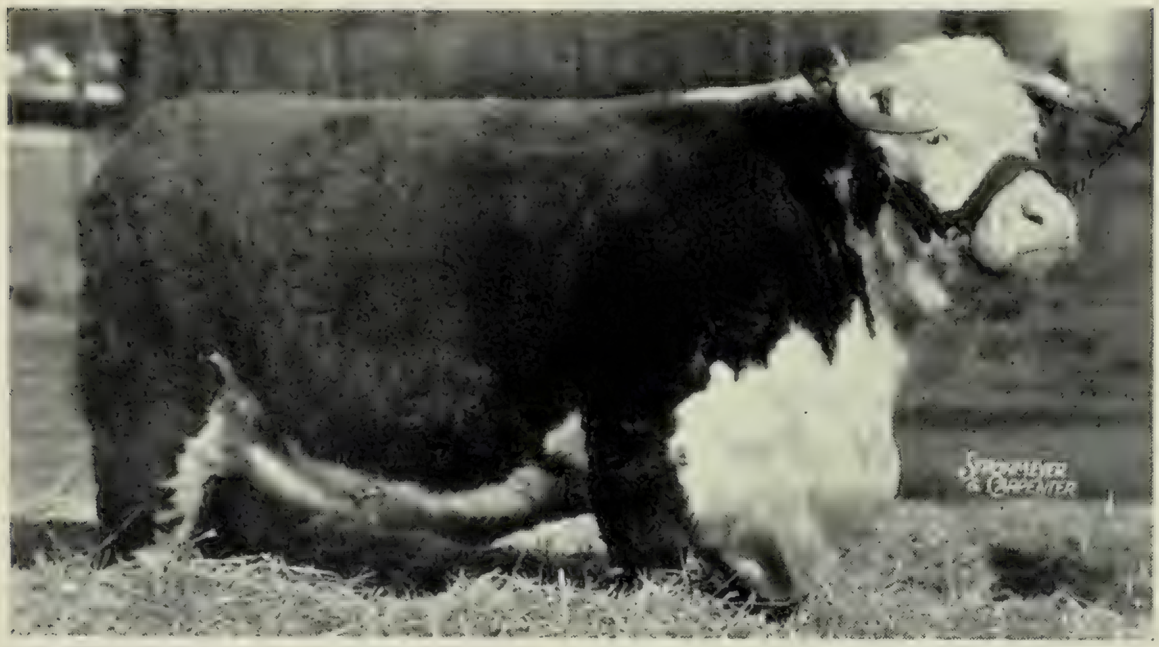


Fig. 133. Miss Coronet 85th. An excellent specimen of the Hereford breed.

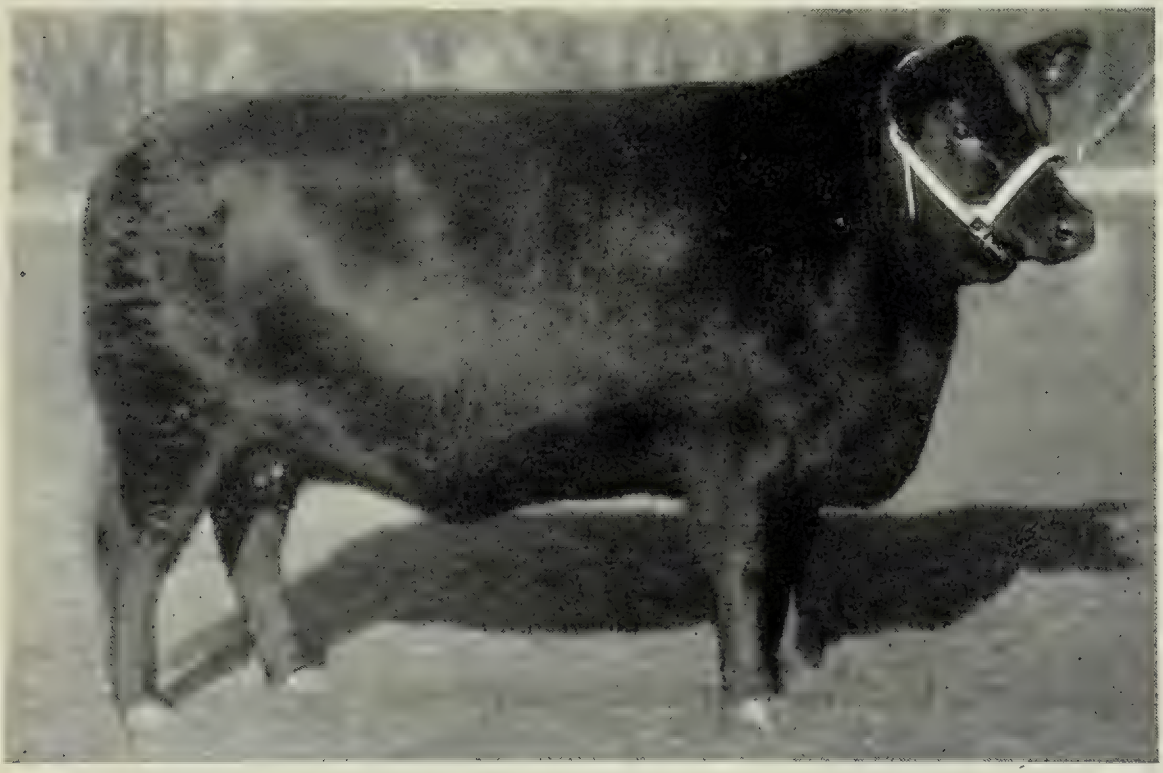


Fig. 134. Aberdeen-Angus female. What characteristics of the beef type are found in this animal?

also white animals may be seen. The Polled Durham is really a Shorthorn without horns.

Certain strains of Shorthorn which are valuable producers of milk as well as of beef have been developed.

(b) *The Hereford.* Herefordshire in the West of England is the home of the very hardy Hereford breed. The body is dark red in colour with white on the legs, crest and underline. A white face is characteristic of the breed. Hereford cattle maturing quickly and producing a relatively small quantity of milk are distinctly animals of the beef type.

(c) *The Aberdeen-Angus.* In Aberdeenshire, Scotland, was originated a breed of black hornless cattle. They are easily fattened for market. Part of their popularity is due to the small amount of offal when they are butchered.

PROBLEM VI: What are the chief cuts of beef?

The cuts of beef.

A visit to a butcher's shop will reveal the fact that the most valuable parts of the animal's carcass are the loin, which includes the short loin and the sirloin or loin end, the rib, and the round. The lowest prices are paid for the flank, plate and shank. One can readily understand why breeders pay so much attention to the amount of flesh on the back of an ox.

Comparison of weight and value of cuts of beef.

Cuts in order of retail price	Percentage of carcass (Weight)	Percentage of carcass (Cost to retail customer)
1. Loin and ribs	Sirloin 9 Short loin 8 } 26 Rib 9	40
2. Round and rump	24	25
3. Chuck	26	20
4. Flank, plate, brisket and shank	24	15

The selection of beef.

When purchasing beef, the customer takes into account factors such as soundness, tenderness, flavour and price.

Sound beef has a faint characteristic fresh odour, is uniform in colour and velvety in appearance. Soft, spotted or discoloured flesh should not be bought.

A number of circumstances affect the tenderness of beef. Among them are the age of the animal, its condition and the part of the carcass from which the cut is taken. The flesh of young cattle is more tender than that of old ones, but is deficient in flavour. It is said that the full flavour is not attained until the animal is from two and a half to three and a half years old. Animals which are lean when slaughtered have tough flesh.

Exercises:

1. Before our modern beef breeds were developed cattle could not be fattened in less than five to seven years. To-day a beef animal may be marketed when twenty to thirty-six months old. Of what importance is this change to the farmer?
2. Find the current price per pound of cuts of beef taken from different parts of the carcass. What is the cause of the difference?

PROBLEM VII: What are the characteristics of dairy cattle?

Breeders of dairy cattle have had as their objectives the development of animals which would give a large flow of rich milk for a longer than average period after calving.

Since the cow manufactures milk from what she eats, she should have a digestive system capable of holding and treating large quantities of food. Hence, in a dairy cow one looks for a large barrel. This demands length and depth of body. The depth should be more pronounced in the rear than in the front half so that when viewed from the side or the rear the dairy cow is roughly wedge-shaped.

Large quantities of milk cannot be given for years by a cow of weak constitution. Hence, the judge or buyer of dairy cattle, seeking evidence that the heart and lungs are adequate to their task, looks for a wide deep chest and well-sprung fore-ribs.

Naturally, there is much attention given to the udder. It should be capacious and the quarters equal in size. At the rear, the udder should extend up between the thighs. The material from which the milk is made must come from food eaten and digested. This material is borne to the udder in the blood. Consequently, if there is not a substantial flow of blood to the udder one would not expect a plentiful supply of milk. Now, along the abdomen of the cow one may see veins which carry blood from the udder to the heart. If these veins and their branches are prominent, it is taken as evidence that much blood is leaving the udder, and consequently that much enters it. Where the veins pass upward, there are openings known as 'milk wells'. They should be large.

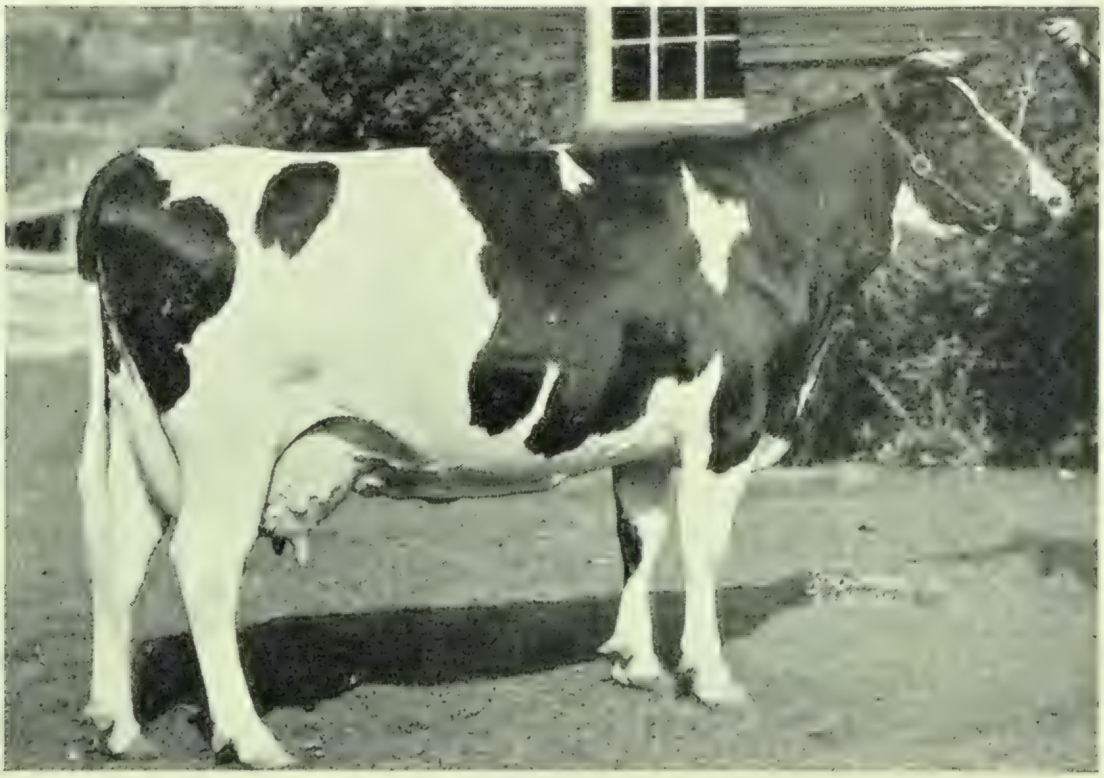


Fig. 135. A splendid cow of the Holstein-Friesian breed.

A dairy cow cannot grow fat and supply a large volume of milk at the same time. Therefore, one looks for spareness of form.

Brief descriptions of certain breeds of dairy cattle follow.

(a) *The Holstein-Friesian.* Along the shores of the North Sea, in Friesland between the Ems and the Rhine, there lived, more than two thousand years ago, a race of hunters, herdsmen and fishermen. Their wealth consisted mainly of cattle which are believed to be the ancestors of the modern Holstein-Friesian breed. Holstein-Friesians, black and white in colour, are the largest of the dairy breeds and give a very large volume of milk. Some of the cows have produced over fifteen tons of milk—more than twenty times their weight—in a year. This milk yielded half a ton of butterfat.

(b) *The Ayrshire.* The hardy Ayrshire breed had its origin in the county of Ayr in Scotland. In colour the animals are brown and white. Large horns with an outward and upward curve are characteristic. Among the reasons for the popularity of this breed are the richness of the milk in butterfat and the readiness with which the cow converts feed into milk.

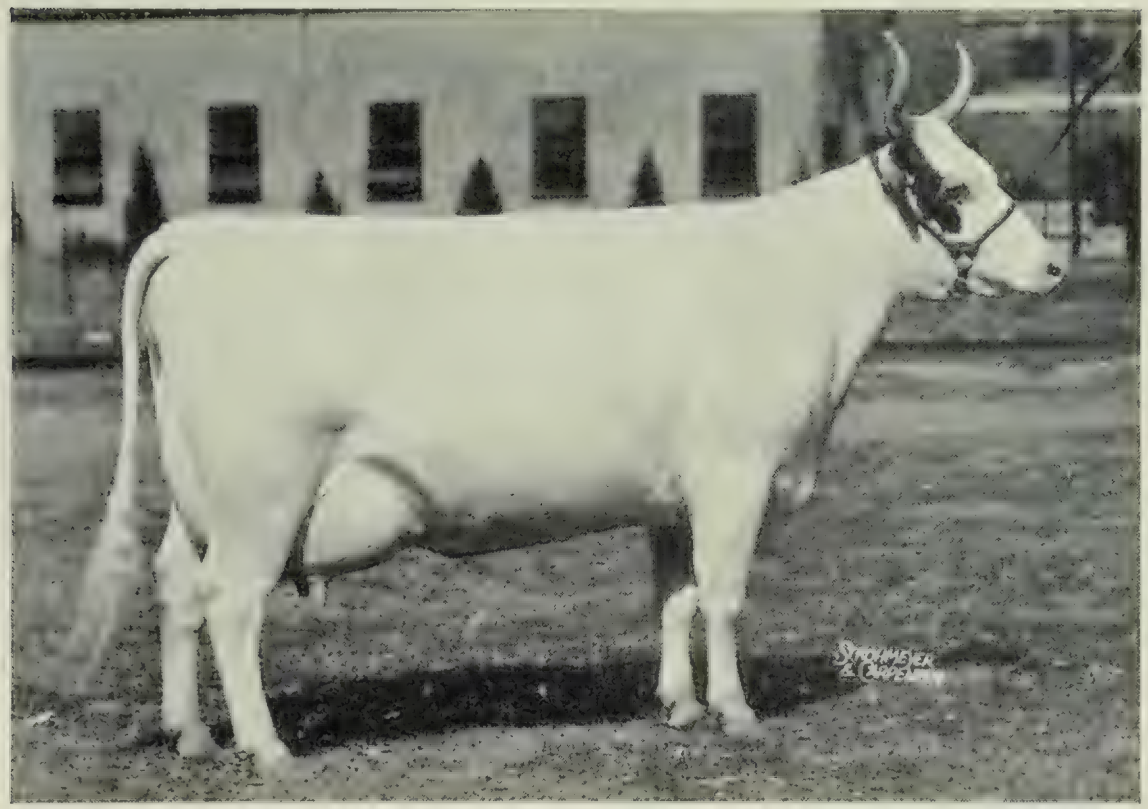


Fig. 136. An Ayrshire cow. Notice the typical horns.

(c) *The Jersey.* Not far from the French shore of the English Channel is a group of islands which have been under the British Crown for more than 700 years. Jersey, the largest of the Chanel Islands, contains about 40,000 acres. A law was passed in 1763 which forbade the importation of cattle to the island. Even to-day imported cattle must be slaughtered within twenty-four hours. While the Jersey cow does not give a large quantity of milk, she has won fame for the high yield of butterfat, the average being over five per cent. The animals are small and fawn-coloured.

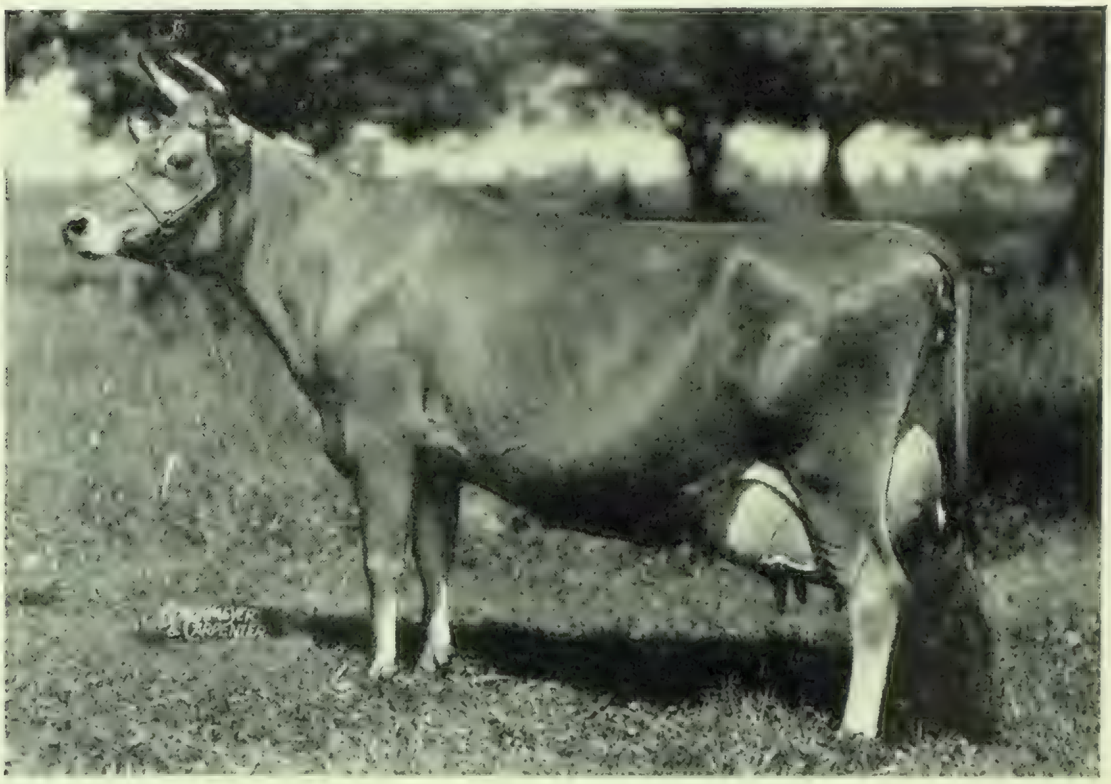


Fig. 137. A Jersey animal. The milk of these cows is richest in cream.

(d) *The Guernsey.* Guernsey, the second largest of the Channel Islands, is the home of the breed bearing its name. The cows give more milk than do Jerseys but, although quite rich, it does not contain as much butterflat as that from the cows of the sister Island. Guernsey cattle are larger than Jerseys. Their colour is fawn with white markings.

(e) *The Canadian.* The Canadian cattle are descended from stock brought from Brittany and Normandy by early settlers in the Province of Quebec. They are about the same size as the Jersey but sturdier in appearance. Their colour is black, brown or dark brown. A moderate volume of milk, comparable in richness with that of the Guernsey is yielded.

(f) *The Shorthorn.* We have previously referred to the fact that certain families of shorthorns with dairy qualities have been developed. (p. 190).

PROBLEM VIII: **Is there any variation in the composition of milk?**

While we are concerned here with cow's milk, it may be mentioned in passing that there is a considerable difference in the milk given by certain mammals. For instance, mare's milk contains water to the extent of ninety-one per cent while that from sows has only eighty-one per cent. Even in the case of animals belonging to the same group, there are variations. This is illustrated by the average percentage of butterfat in the milk of cows belonging to different breeds—

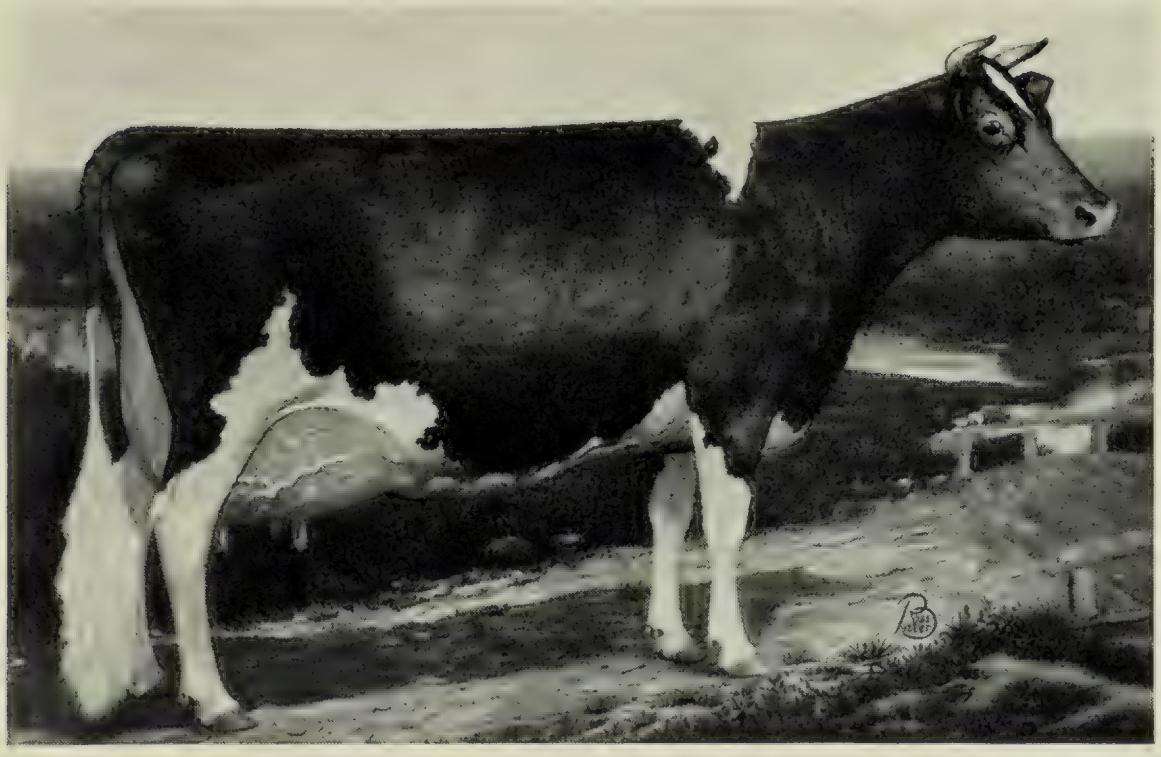


Fig. 138. Guernsey cow. Standard type. Approved by the Canadian Guernsey Breeders Association.

	Average percentage of butterfat.
Holstein-Friesian	5.5
Ayrshire	3.8
Guernsey	5.0
Jersey	5.4

Also, we find variation in cows of the same breed. Some give milk much richer or much poorer in fat than the average for the breed. Not only are there variations from one kind of mammal to another, and from one individual to another even when belonging to the same breed, but there are also differences in the composition of milk derived from a single animal. Her 'foremilk', that is the portion which comes first from the udder, has very little cream, the 'strippings', or last part, is much richer. Her milk toward the end of the period of lactation contains a higher percentage of butterfat than that given in the first months. Another factor influencing the richness of milk is the season.

PROBLEM IX: What is the importance of the cattle industry in Canada?

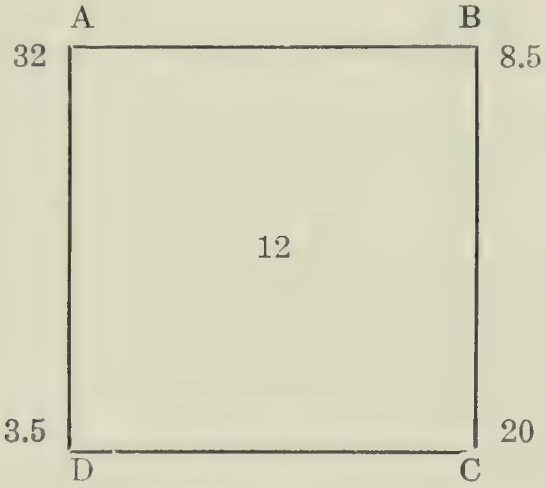
The preceding incomplete list of products helps to convey a rough idea of the great varieties of industries wholly or partially dependent on the nine million head of cattle in Canada. Until 1934, the annual value of dairy products in the Dominion was greater than that of metals, including gold. In that year, for the first time, they fell into second place. Some idea of the importance of the beef industry may be gathered from the fact that from 300,000 to 400,000 tons of the meat are consumed annually by Canadians.

Exercises:

1. What percentage of butterfat is required, by law, in milk offered for sale? Consult your local milk companies.
2. A farmer has two cows each of which gives 6,000 pounds of milk annually. The percentage of butterfat in one case is 3.3 and in the other 4.9. How much butterfat was obtained from each cow in a year? At the current price of butterfat calculate the difference in gross receipts from the two animals.
3. One cow produced 10,460 pounds of milk containing 3.2 per cent butterfat. Another gave 5,840 pounds testing 5 per cent. At the current prices of butterfat and skimmed milk find the difference in gross receipts.

4. A dairy wishes to mix cream containing 32% butterfat with whole milk testing 3.5% in order to produce ice-cream with 12% butterfat. To obtain the proportions in which the cream and milk should be mixed the following device is used—

In the square ABCD the numbers 32 and 3.5 are placed at A and D respectively. At the centre is written the number 12. At B is the difference between 12 and 3.5 and at C the difference between 32 and 12. These differences, 8.5 and 20, give the required proportions. Thus, if 20 pounds of milk testing 3.5% butterfat are added to 8.5 pounds of 32% cream the dairy obtains 28.5 pounds of 12% cream.



(a) Test the device arithmetically.

(b) When your knowledge of algebra is adequate to the task, find if the device is a valid one.

H. MINOR STUDY: Other mammals of Western Canada.

Very few of the claw animals have been domesticated. Many of these still remain a danger to life in their native wilds. Man, however, finds in them a profitable source of furs. Bears are plentiful in the foothills and mountain regions of Alberta. For centuries, the beaver was the fit emblem of the fur trade. Beaver skins too were the currency of trade. No longer is the beaver the most important animal.

The following table of fur production should be studied carefully:

Alberta fur production from July 1, 1936, to June 30, 1937, was:

Kind of Fur	Pelts	Total Value
Badger	35	420
Beaver	3,897	55,337
Bear	292	292
Ermine	321,499	353,648
Fisher	37	1,665
Fitch	122	61
Fox (Sil. Black)	19,650	482,407
Fox (Cross)	2,028	40,255
Fox (Red)	2,490	27,016
Fox (Blue)	332	4,980
Fox (White)	7	115
Lynx	1,560	65,676
Marten	625	19,500
Mink	11,367	150,044
Muskrat	274,640	357,032
Otter	178	2,625
Rabbit	70,203	8,424
Raccoon	142	426
Skunk	23,769	36,841
Squirrel	1,309,239	261,847
Wolf, Prairie or Coyote	25,276	281,827
Wolf, Timber	435	10,962
Wolverine	17	55
House Cats	275	41
Wild Cats	3	3
Total	2,068,118	$2,161,499

PROBLEM I: How are animals skinned and the skins preserved?

In the year 1936 there were over 500 fox and fur farms in Alberta. In the late fall the foxes are caught and killed by means of an injection from a needle between the two ribs over the heart. The foxes are laid out in the snow to cool before being skinned.

The skinner starts from the feet upwards. The tail is boned. When skinning is complete, the skin has been turned inside out. It is put on a stretching board and extended to its full length. Surplus flesh and fat are scraped from the 'green' fur by means of a short bone taken from the shin of a horse or cow. The skins are then thoroughly dried in the drying shed.

Before the furs are shipped to market, all grease particles which adhere to the pelt are taken off by means of hardwood sawdust. The sawdust is removed and the fur is fluffed in a machine known as the "fluffer", a churn-like machine with wire netting on the outside.

I. MINOR STUDY: Insects are enemies and allies of men.

PROBLEM I: How are insects harmful?

We are shocked by the losses sustained through fire and flood, but year after year thousands of armies, each numbering billions, make warfare upon us. Yet we are not greatly impressed because we have become accustomed to paying tribute. The invading hordes have a variety of tactics. Some cause us pain and annoyance, some invade our homes and devour our clothes, some enter the bodies of our cattle and ruin their hides, others lay waste our forests, fields, gardens and orchards. In an average year, insects destroy as much wealth as our gold mines produce.

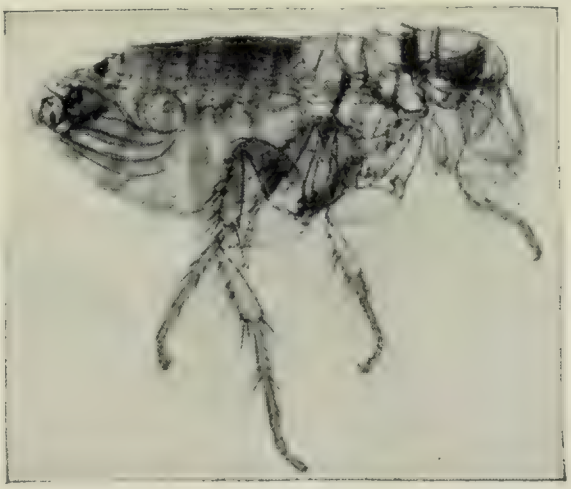
Fortunately, we are not completely powerless. The Dominion and Provincial Governments have in their service highly trained men who are constantly devising effective means of keeping our insect enemies within bounds. Birds are valuable allies; without them we should have to abandon the struggle. Then there are certain insects which prey upon the harmful ones and destroy them in very large numbers.

You may find it of interest to learn a little about these insect enemies and allies of men.

Injurious insects

(a) *Injury to man and animals.*

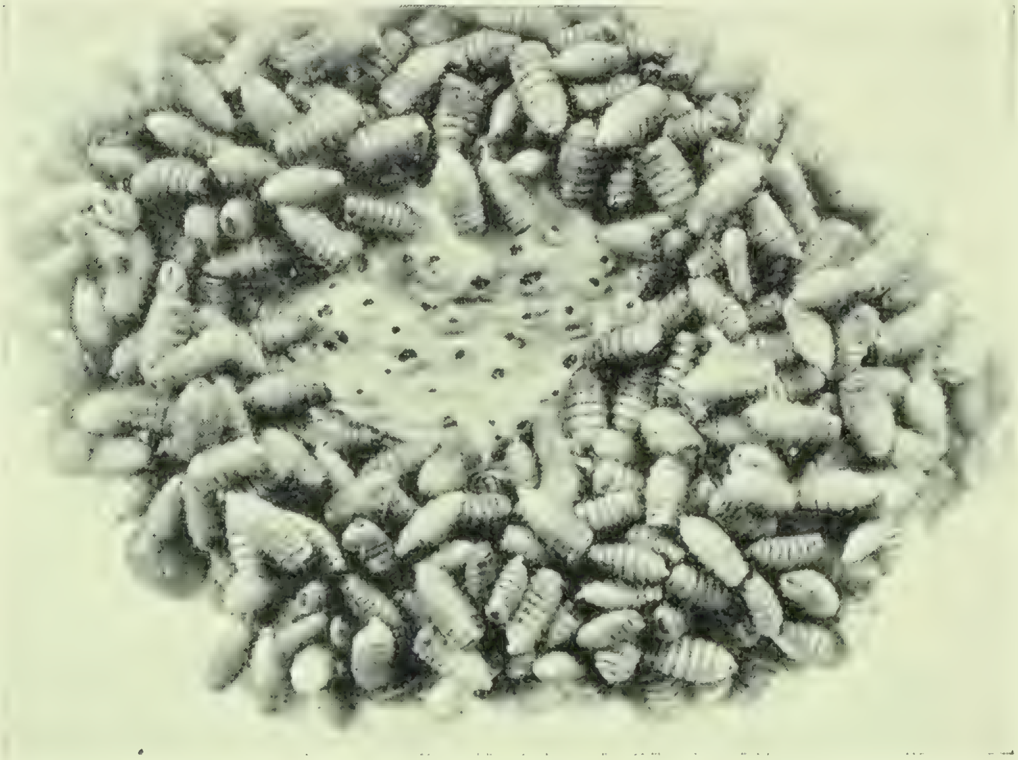
Lice and fleas are parasites that live on the bodies of animals and of persons whose conditions of living are unclean. By means of



(Copyright by Gen. Biol. Supply House, Chicago.)

Fig. 139. Dog flea.

their piercing and sucking mouth parts they penetrate the skin and feed on blood. Bedbugs are rust red insects that shelter in cracks and come out at night in search of a victim. They are disagreeable, not only because of their blood-thirsty habits, but also on account of their unpleasant odour. Some insects enter the bodies of horses and cattle where they live as internal parasites. Hides worth millions of dollars are ruined yearly by warble fly larvae.



(*U. S. A. Bull. 597.*)

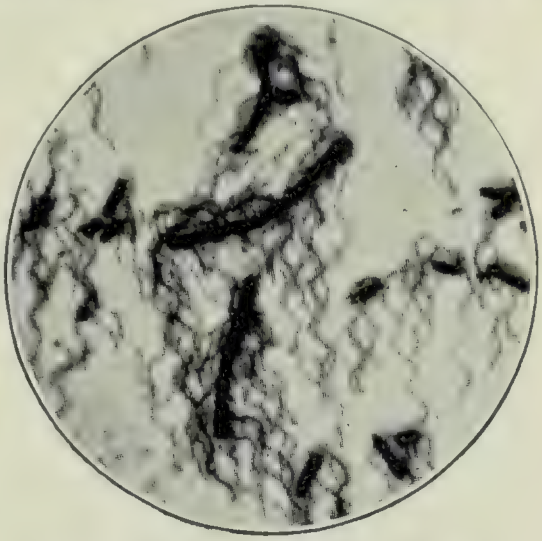
Fig. 140. Larvae of the horse bot on the lining of a horse's stomach. Notice the holes left when some of the bots were detached.

The activities of mosquitoes and black flies are too well known to require description.

Insects carry disease germs from one infected person or animal to others. Among the most notorious offenders are the house-fly which carries the germs causing tuberculosis, typhoid fever and summer diarrhoea; certain mosquitoes which spread yellow fever and other diseases; the tsetse fly which is the agent by which the dreaded sleeping sickness of equatorial Africa is communicated; and lice, which carry the microbes producing typhus and trench fevers.

(b) *Injury to plants.*

Insects with mouth parts fitted for biting attack roots, leaves and fruit. They form tunnels within stems, eating as they go. Others with piercing and sucking mouth parts puncture the leaves, bark, or fruit and absorb the plant juices. The very small parasitic plants or animals that cause diseases are frequently carried by insects from infected to healthy vegetation, or, borne by wind, they gain admittance through the wounds.



(Courtesy Gen. Biol. Supply House.)

Fig. 141. Typhoid fever germs very highly magnified. Each is about 3/1000 of a millimetre in length.

(c) *Damage to food, clothing, and articles made of wood.*

If account could be kept of the annual losses in stores, restaurants and private houses caused by insects eating food or rendering it unfit for human consumption, the total would undoubtedly be an enormous sum. Among these pests are the cockroach, a filthy insect, the pea and bean weevils, and the larder beetle. The drug store beetle has been known to eat, not only chocolate and pepper, but also some forty different drugs, including kinds poisonous to human beings!

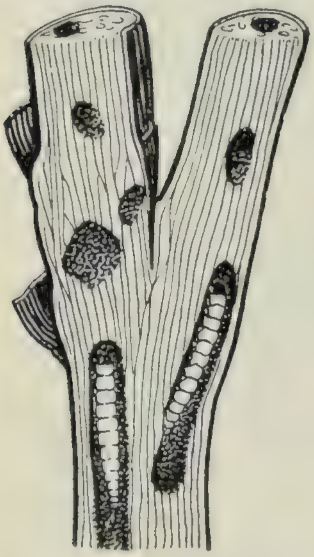


Fig. 142. The European corn borer.

Clothes moths are uninvited guests in many households. Their larvae devour woollens, furs and rugs with a zest heartbreaking to the thrifty housewife.

In the tropics, and in some temperate regions, the termite or so-called 'white ant' destroys anything made of, or derived

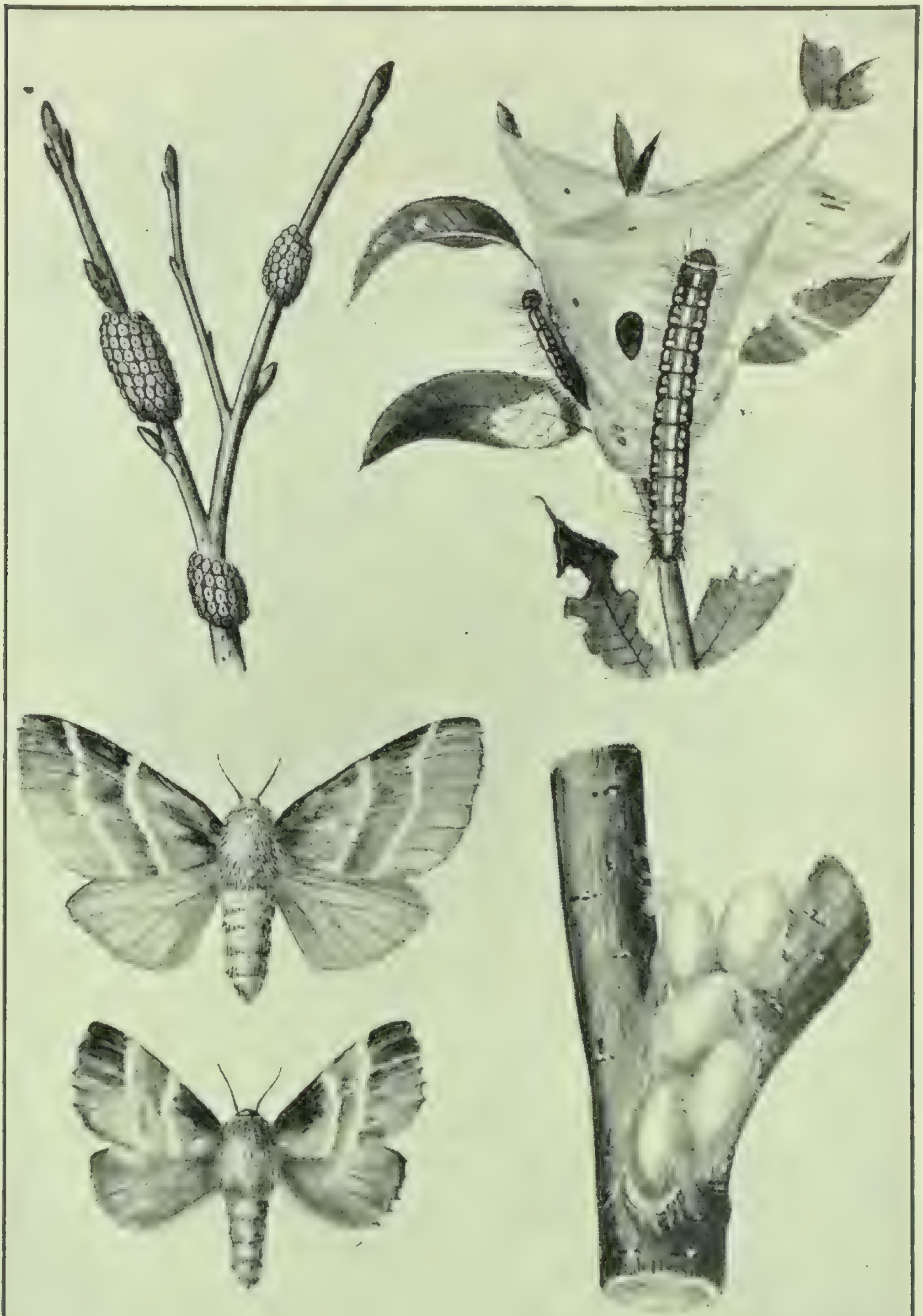
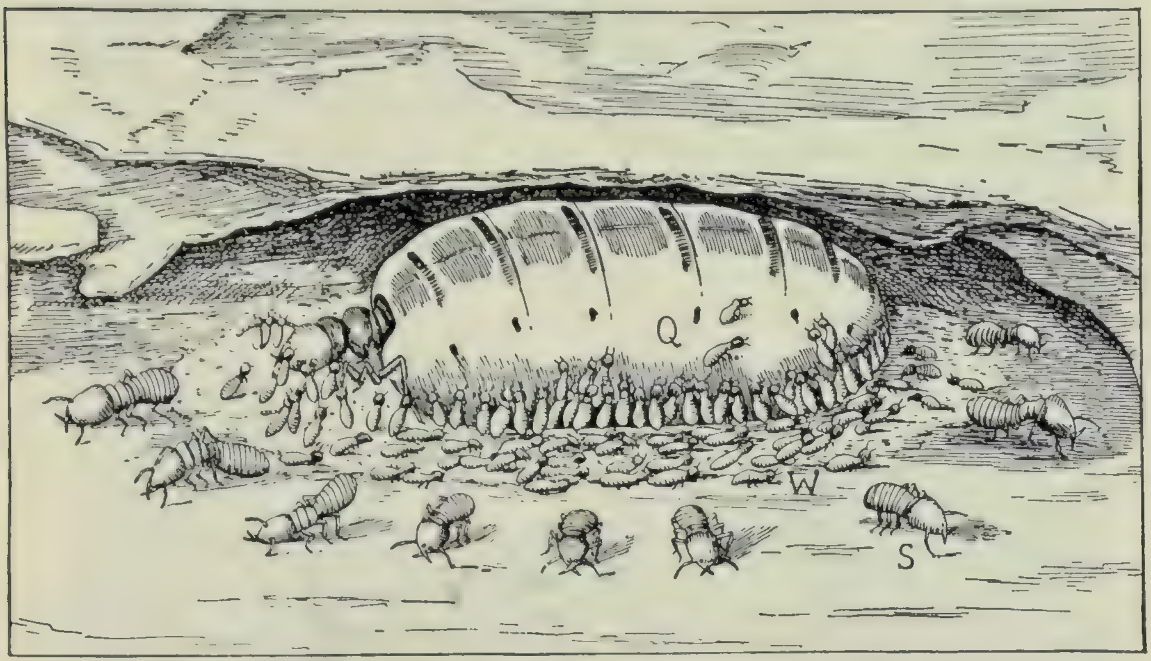


Fig. 143. Life history of the eastern (or American) tent caterpillar.

from wood, for example books, telegraph poles, furniture and wooden foundations. It is interesting to learn that this woody diet is digested for the termite by very small animals which are their internal parasites. If these one-celled parasites were absent, the termite would starve to death even in the presence of an abundance of food.



(From "Biology for Everyman" by Sir J. A. Thomson. Courtesy J. M. Dent & Sons.)

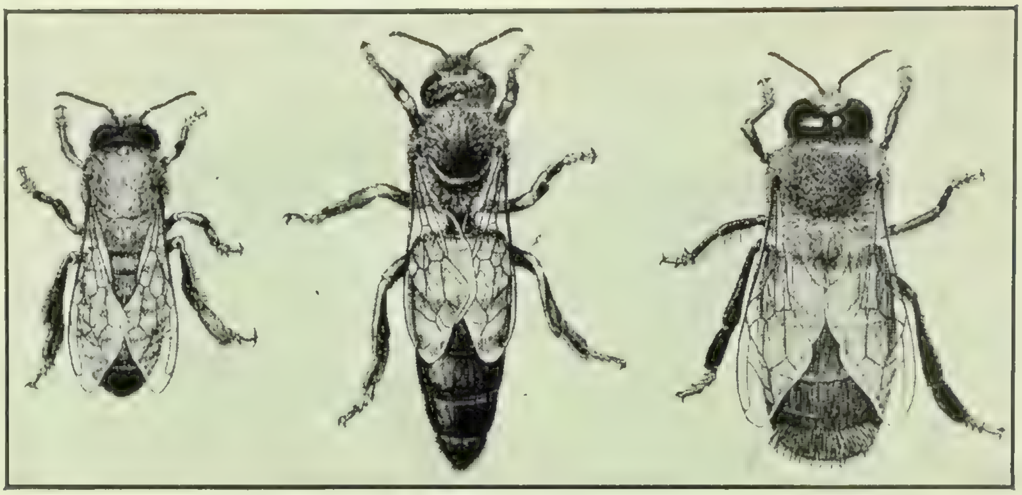
Fig. 144. A colony of termites or 'white ants'. Q, queen; S, soldier; W, worker.

PROBLEM II: How are insects beneficial?

It is but fair to present another aspect. There are a number of kinds of insects which perform services useful to man.

(a) *Insects from which useful products are obtained.*

Honey-bee workers are indefatigable collectors of nectar. The sweet liquid is stored in a cell where it loses water by evaporation and after 'ripening' becomes honey. Honey is made by bees for their own benefit and is stored to serve as a reserve during winter when nectar cannot be obtained. Man uses this stored food just as he avails himself of food reserves in the potato tuber and in the roots of the carrot and

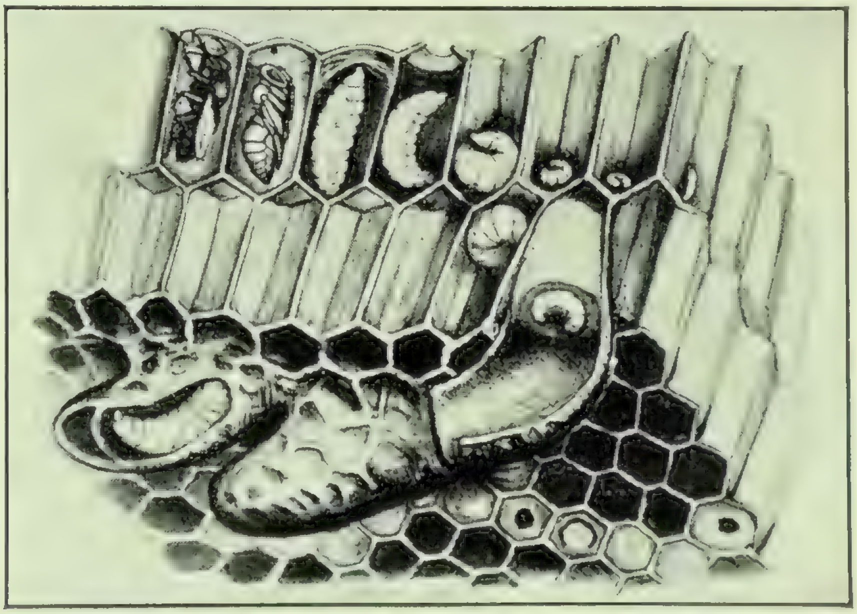


(*Courtesy U. S. Dept. Agr., Bur. of Ent. and Plant Quarantine.*)

Fig. 145. *Left to right.* Worker, queen and drone honey-bees.

turnip. Beeswax, a product for which man has a number of uses, is also manufactured by honey-bees.

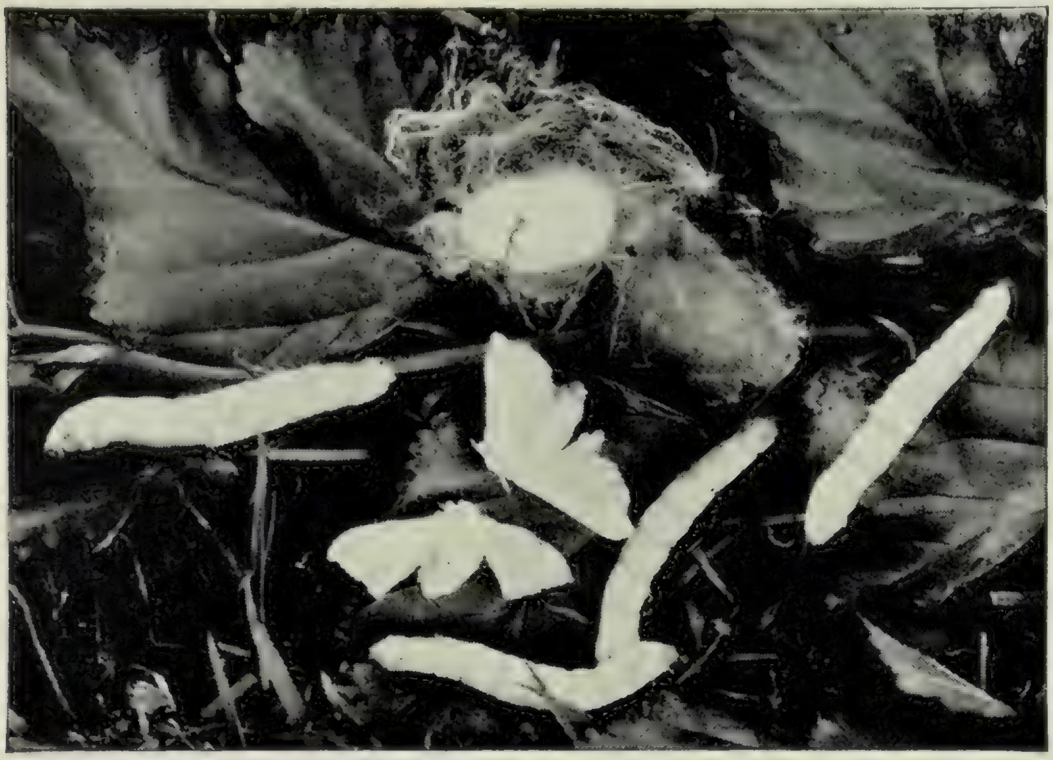
Much more important commercially than honey is true silk, obtained from the protective case or cocoon constructed from saliva by certain moth larvae when pupating. Some two thousand billion silkworms die annually in order that ladies may be clad in silk. The true silk industry, which is more than 3,500 years old, originated in China.



(*Courtesy U.S. Dept. Agr., Bur. of Ent. and Plant Quarantine.*)

Fig. 146. Honey-comb showing egg, larva and pupa of honey-bee.

Shellac, used in the manufacture of an extensive list of articles such as varnish, electrical equipment and linoleum, is made from the secretion of a forest insect of India. Those orchard pests, the San José and oyster-shell scale insects, are relatives of the lac insect.



(*Courtesy American Museum of Nat. Hist.*)

Fig. 147. Silkworm moths, larvae and cocoon.

Cochineal, a reddish pigment used in colouring certain foodstuffs and also as a cosmetic, is made from a scale insect which feeds on the prickly pear.

Galls, which form on plants as a result of the activity of insects, are used in the manufacture of inks and dyes.

(b) *Predaceous and parasitic insects.*

Valuable as the silkworm and honey-bee are, their work must rank far below that of the predatory and parasitic insects. These are our most effective allies in the war against their injurious relatives.

One of the best known predaceous insects is the ladybird beetle which eats those sap-suckers, the plant lice or aphids.

Another is the dragonfly which, in the water, devours insect larvae, in the air, the mature forms.

Ichneumons, braconids and tachina flies are important aids in the control of injurious insects. These deposit their eggs on or in the bodies of caterpillars. When the larvae emerge, they have not far to seek for their food.

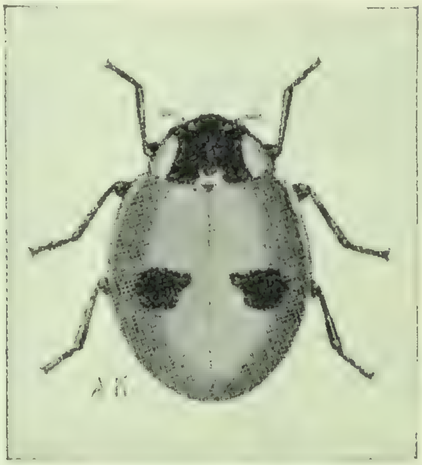


Fig. 148. The ladybird beetle, one of our insect allies (Enlarged)

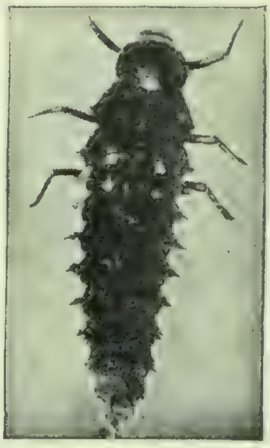


Fig. 149. The larva of the ladybird beetle. (Enlarged)

Tachina flies are hairy grayish or brownish two-winged insects which resemble the horse-fly. They frequent flowers or other vegetation in search of caterpillars.

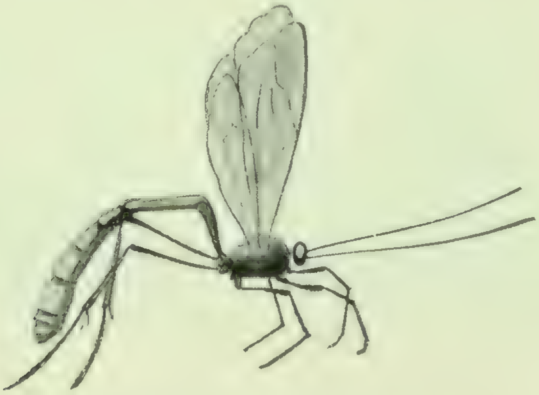
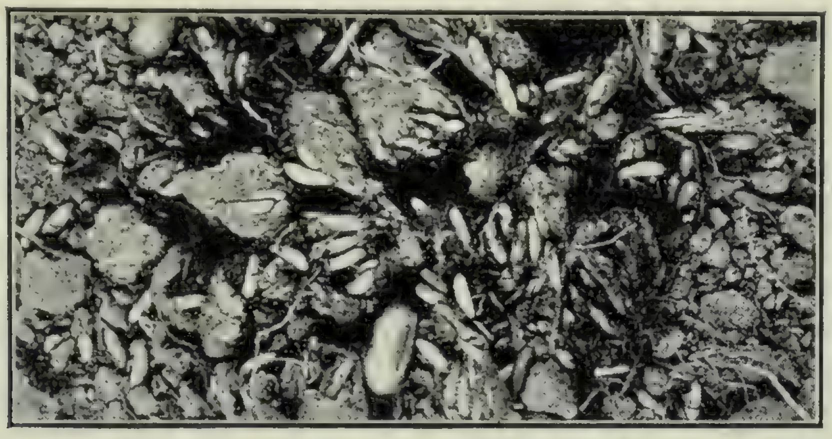


Fig. 150. An ichneumon fly.

The female tachina fly fastens her eggs to the host larva or to the foliage on which it feeds. The minute maggots enter the victim, and find food and shelter there. They do not kill the host but usually allow it to complete its growth. Frequently, the host attains the pupal stage, but then it dies. By this time, the tachinid larvae have pupated. The pupa is succeeded by the adult fly.

Cabbage butterfly caterpillars, and the eastern and the forest tent caterpillars are among the insects destroyed by tachina fly larvae.



(Courtesy Missouri College of Agric.)

Fig. 151. The blister beetle larva (middle foreground) is feasting on the eggs of a grasshopper.

Often, parasites have their own parasites, and there may be parasites of the parasites of the parasites. Of these last three groups, the first and third are obviously beneficial, and the second injurious. Such a condition has prompted the lines

"Big fleas have little fleas
Upon their backs to bite 'em;
Little fleas have smaller fleas,
And so ad infinitum."

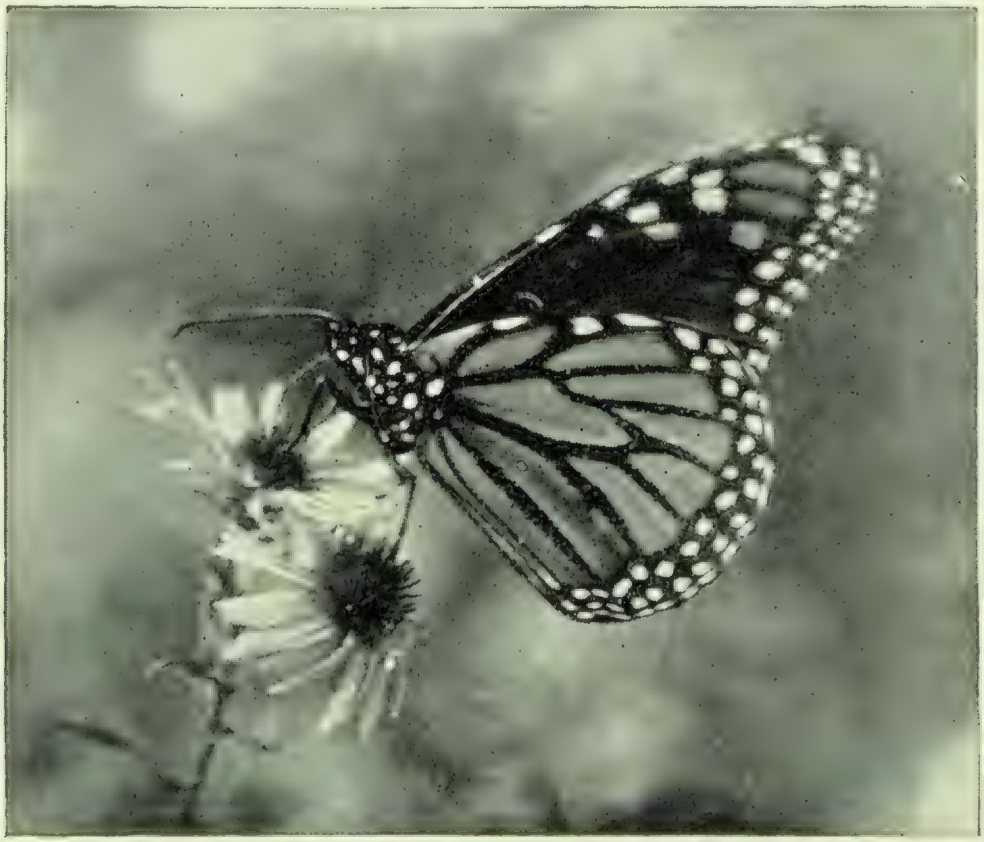
See also pages 166-168.

(c) *Injury to weeds.*

It should not be thought that insects select valuable plants only on which to feed; weeds are not disregarded in the quest for food. Milkweed, for instance is attacked by the caterpillars of the monarch or milkweed butterfly and also by a beetle. The prickly pear (p. 163), a native of America, was introduced to Australia. Spreading at the rate of a thousand square miles each year, it made useless many millions of acres of land. Other methods of eradication having failed, the risky, but successful, experiment of importing insect enemies of the plant was tried. Since there was the danger that the introduced insects would turn their attention to plants other than the prickly pear, careful tests were made before they were released. In North America, the Colorado potato beetle formerly fed on wild plants; now it infests potato plots.

(d) *Insects as agents in cross-pollination.*

If insects were destroyed, the fruit-growing industry would be ruined, clover and alfalfa would disappear and we would be deprived of a number of vegetables and many flowers.



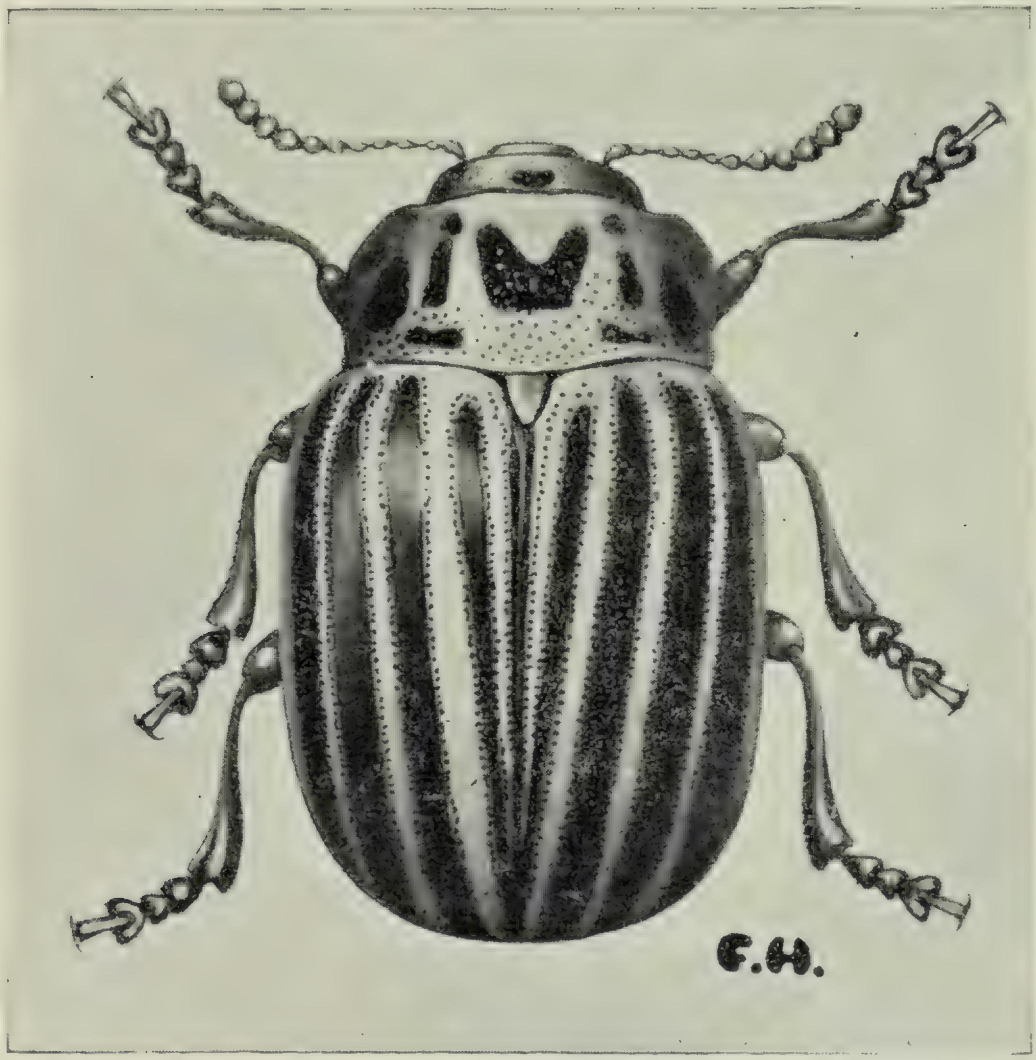
(Courtesy Nat. Museum of Canada.)

Fig. 152. The monarch or milkweed butterfly. This insect, like many birds, migrates southward at the end of the summer.

(e) *Insects as food for human beings and animals.*

Insects have long been an article of diet among primitive races. Crickets, ants, and certain larvae are among the kinds that have found favour. We are told that the Eskimo removes the warble-fly grubs from the skin of the caribou. These, although tasteless and watery to the white man, are eaten with relish.

They are a substantial part of the food of many desirable birds and are consumed in quantity by poultry kept out of doors. Certain immature forms, such as caddis larvae, bloodworms, or midge larvae and mayfly nymphs, are important elements in the food of fresh-water fish.



(*After Gibson, Bull. 99, Dom. Dept. Agr.*)

Fig. 153. The Colorado potato beetle.

(f) *Insects as scavengers.*

Insects devour the decaying bodies of dead animals. The

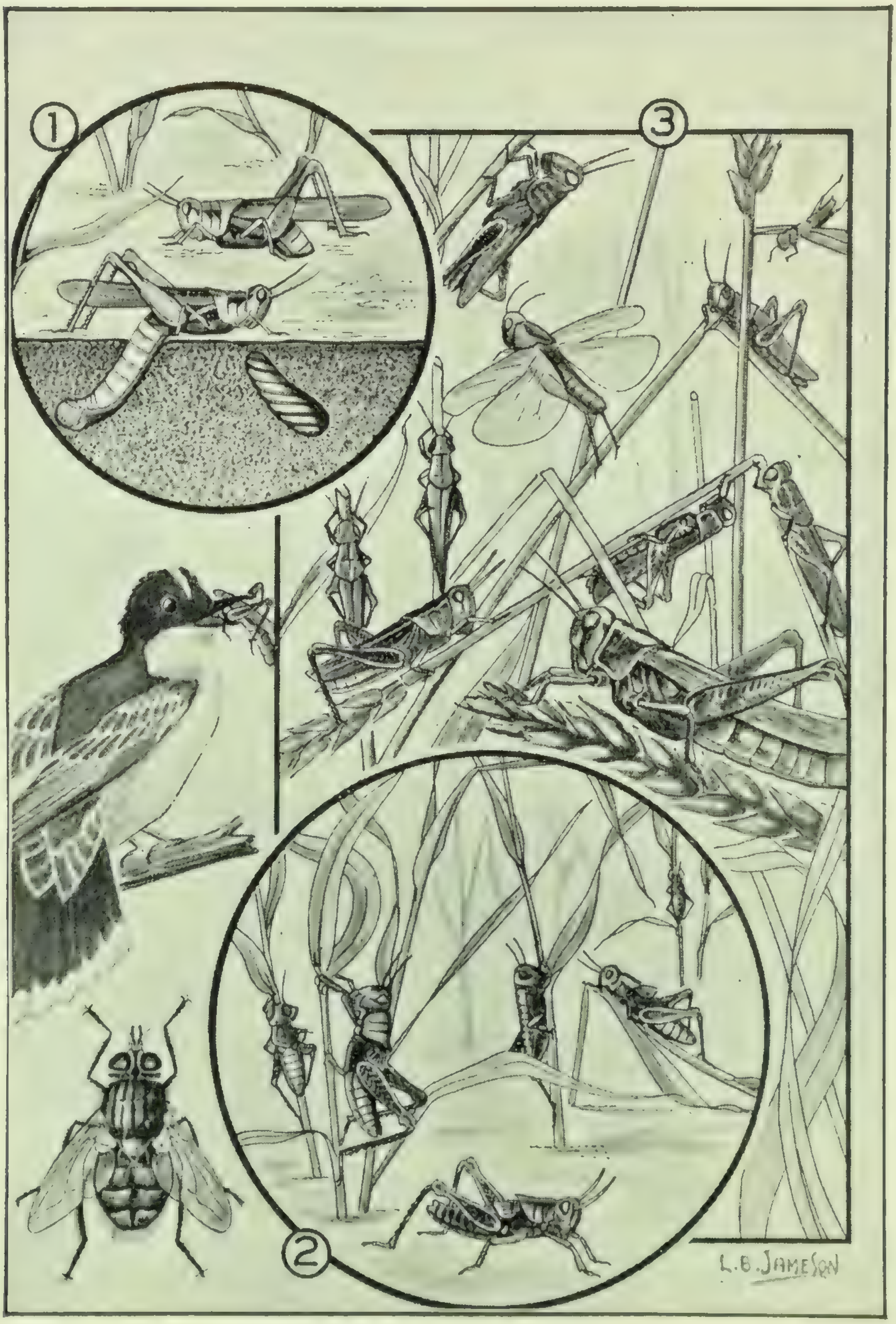


Fig. 154. Activities of locusts in autumn (1), spring (2), and summer (3). The kingbird and tachina fly are enemies.

termites, to which we have already referred, perform a useful service in the tropical forests by clearing up dead and decaying wood.

(g) *Insects as a factor in soil fertility.*

Darwin drew attention to the influence of earthworms on the fertility of the soil. It is believed by some authorities that insects are no less valuable in this connection. The insect population of the soil is very variable; estimates range from 1,000,000 to 65,000,000 per acre. By making tunnels, the insects admit air to the soil. In life their waste products, and in death their decaying bodies, contribute to the soil's fertility.

1. Inspectors employed by the Dominion Entomological Branch keep a watchful eye on importations of plants and plant products. Why is this vigilance necessary?
2. Give examples, that have come under your notice, of the destructiveness of insects.

PROBLEM III: What is the life history of the grasshopper?

In late summer or autumn the female uses her strong four-pointed "ovipositor" or egg-placer to make a pod-like structure just below the surface of the ground. The cavity is lined with a gummy substance which, when hard, excludes moisture. Then the eggs, from thirty to a hundred in number, are laid. Just as annual plants project their form of life over winter in the seed stage, so the continuance of grasshoppers depends on their eggs. In spring the immature grasshoppers emerge. These "nymphs", as they are called, resemble the adult but are smaller and lack wings. Their food is the same as that of the mature insect. One might wonder how these creatures sheathed in armour could possibly grow. The nymph solves this problem by getting rid of its horny skin from time to time and growing a new one. In June or July, the nymph ceases moulting. It has attained its full size and possesses wings.

Observations to be made indoors on the living insect.

Grasshoppers of different stages of development should be collected and kept alive in glass vessels covered with netting. A sod may be placed in the bottom of the container. The insects will eat grass, lettuce, or apple cut in thin slices.

(1) *Movements.* NOTE: how the grasshopper walks; the order in which its legs move; how it climbs up a stem of grass; the structure of the lower part of a leg; the position of its legs when about to jump; the legs of most use in jumping; how the abdomen moves as the insect breathes; how the grasshopper eats; how its jaws move; the effect of touching a 'feeler' or antenna.

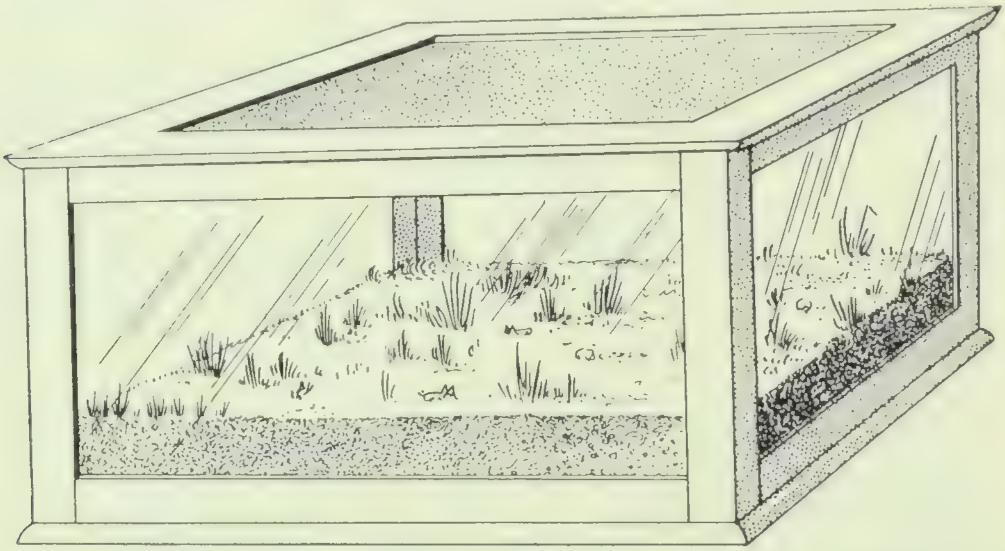


Fig. 155. You will find it interesting to observe the behaviour of grasshoppers.

(ii) *Development.* Observe the difference in appearance between the older and younger grasshoppers. (Some of the younger insects should be kept for a time so that the process of moulting may be observed.)

PROBLEM IV: What is the life history of the cabbage white butterfly?

One of the many marvellous things in nature is the life history of an insect like the cabbage butterfly.

From the tiny yellow egg laid in May emerged a little larva. It entered the world with an enviable appetite but without cause for worry. Its mother had diligently sought for one of the few plants on which her offspring can feed and on it she had deposited her eggs. When she had discharged this duty, she took no further interest in her family.

The caterpillar sought in vain to satisfy its hunger on the cabbage, cauliflower, turnip, radish or other plant of the

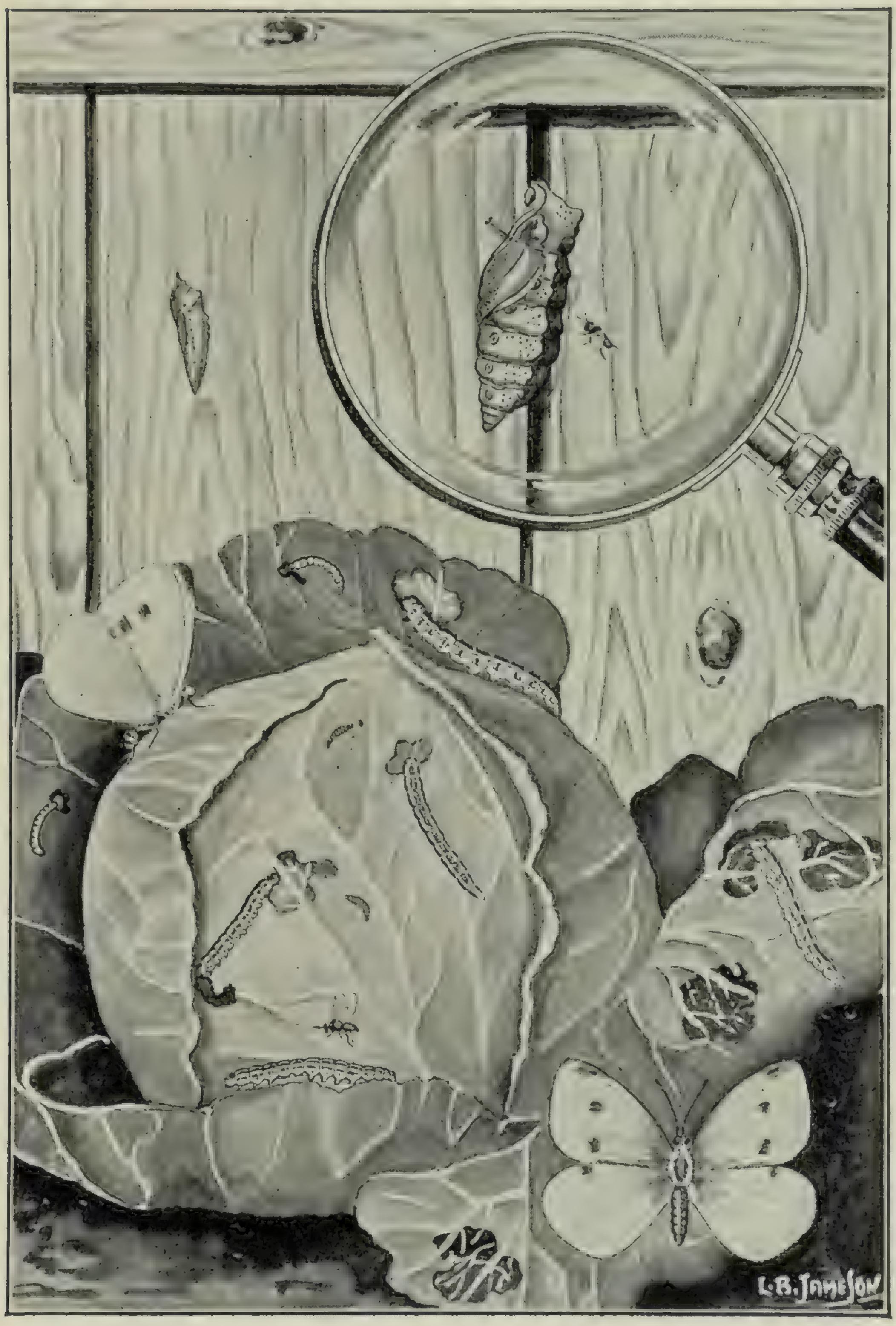


Fig. 156. The imported cabbage butterfly. Can you find the insect seeking a caterpillar in which to deposit eggs? There is another approaching a pupa.

mustard group, on which it found itself. Its growth was rapid; as it grew, its appetite increased.

From time to time it stopped feeding and shed its skin. There was always a new skin underneath to replace the one discarded. Its greenish colour made it rather inconspicuous to birds, but this was not its only protection. Few birds, except the house and chipping sparrows, like to eat them.

When it attained its full size of about an inch and a quarter the larva crawled away to a weed at the edge of a garden. Some of its relatives preferred the fence, others a building. There it fastened itself by a silken girdle and changed into the rather angular pupa. During this stage it did not eat; indeed, if undisturbed it did not move. Yet there were strange happenings inside. A new creature, very different from the worm-like larva, was being developed. In a week or two, the change was complete, the skin split and the adult butterfly came out. It was very helpless at first, with no strength in its limp crumpled wings Soon, however, they became rigid and the butterfly took to the air. The one we have in mind was a female. She had two black spots on each forewing; the male has only one.

Before long, the new butterfly laid her batch of eggs and the whole story was repeated. The larvae and pupae found in late summer probably belonged to the third generation developed in one season. Pupae formed at the end of the summer remain in that stage until the following spring and then the adults emerge.

We may summarize the life cycle or metamorphosis (Gk. *meta,* after; *morphe,* form) as follows:

Egg → Larva → Pupa → Adult

PROBLEM VI: How can we learn about some of these insect enemies and friends?

In order to learn about some of these insect enemies and friends is is necessary to provide ourselves with a certain amount of equipment.

An insect net.

Obtain a stout piece of wire four feet long and bend it so as to form a hoop. Twist the ends for a length of about three inches and, by means of wire, fasten the hoop to the handle of a discarded broom. Sew cheese cloth around the hoop making a bag a foot and a half in depth.

Insect cages.

Living insects are much more interesting than dead ones and so we provide ourselves with suitable containers in which they may be kept for observation.

1. For small insects such as clothes moths an ordinary sealer covered tightly with a piece of cheese cloth is very convenient.

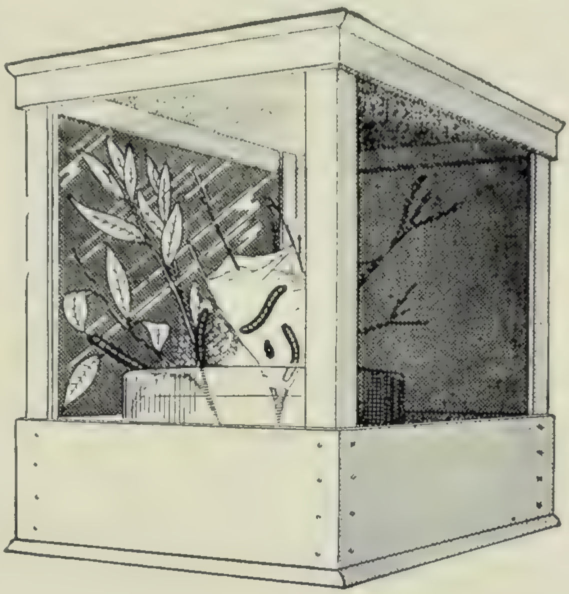


Fig. 157. A convenient type of insect cage.

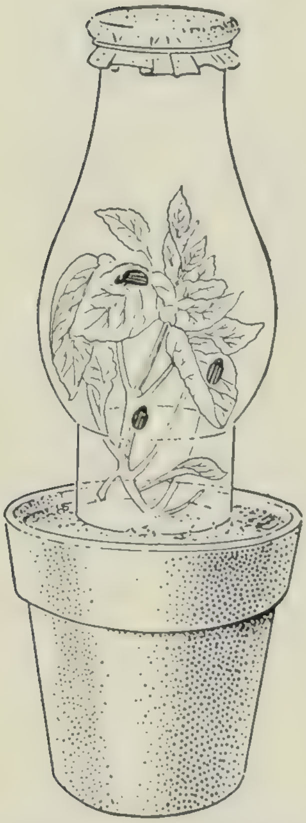


Fig. 158. An easily constructed insect cage.

2. Another container much used is a large lamp chimney the upper end of which is covered by cheese cloth and the lower one inserted into soil in a flower pot.

3. Pupils who have acquired a little skill in carpentry may wish to make a larger cage. Obtain a box with approximately the following dimensions 12″ x 12″ x 24″. Remove part of one of the larger sides and cover the opening with gauze. Replace with glass as much as possible of the wood in the remaining three sides. One pane should be inserted so that it may be raised and lowered. Any hardware man will construct a galvanized iron trough about four inches deep to fit the bottom. This will enable you to keep moist soil in the cage.

The live insects should be supplied with their natural food. It is advisable, whenever possible, to have the plant growing in the container.

Preservation of insects.

It is desirable that each school should possess a collection of insects which includes those selected for study. The collection may be built up gradually from specimens contributed by the pupils. Care should be taken to insure that it is attractive in appearance. A killing bottle, a spreading board, insect pins, labels, and boxes are necessary. The boxes, pins, and labels may be obtained from dealers in school supplies.

A killing bottle.

(*In view of the highly poisonous nature of potassium cyanide the killing bottle is invariably made by, and used under the supervision of the teacher.* The following information should satisfy the natural curiosity of interested pupils.)

Small pieces of potassium cyanide were placed in a sealer to a depth of about half an inch. Paste made from plaster of Paris was then poured in until the cyanide was completely covered. The top of the sealer was put on and a label reading "Insect Killing Bottle—Poison", affixed. When the plaster of Paris had set, a circular piece of blotting paper was placed on top of it.

Fumes from the potassium cyanide pass upward through the plaster of Paris and kill the insects.

(NOTE: Carbon tetrachloride is safe to handle. Pour some of this liquid on some cotton batting placed in the bottom of a sealer. Keep the top on as the liquid evaporates readily and will have to be renewed frequently. This liquid provides a safe substitute for potassium cyanide.)

Preservation of insects with soft bodies.

Caterpillars and other forms with soft bodies may be preserved in vials containing seventy per cent alcohol or eight per cent formalin. The appearance of the collection is improved if the vials are of uniform size and if the little labels are attached at the same height.

If a large number of beetles, grasshoppers, etc., intended for early use are being kept in a sealer, the addition of a small quantity of glycerine to the formalin or alcohol will prevent the insects from becoming very brittle.

Preservation of other insects.

By means of an insect pin passed through the chest region, or in the case of beetles, through the middle of the right wing cover, the dead specimen should be placed in position in the insect box.

Very small insects should be placed sideways in a drop of mucilage on a triangular piece of paper which is no larger than necessary. The insect pin should be passed through the paper close to its shortest side.

Every insect should be mounted at the same distance below the head of the pin.

A neatly printed label should be fastened to the bottom of the box in front of each pin.

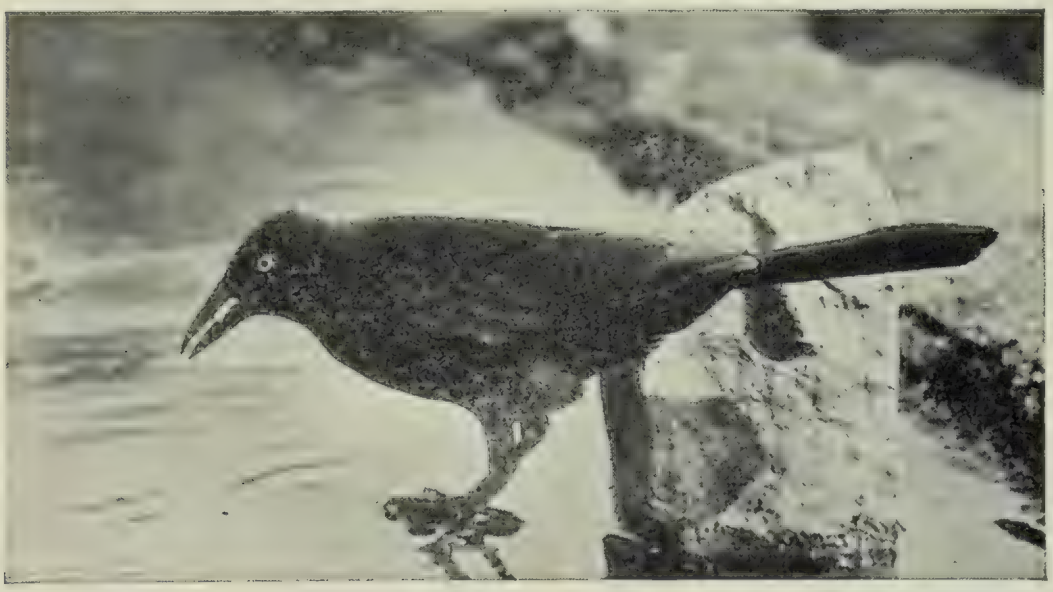
If you cannot identify an insect, send a specimen to the Entomological Branch, Department of Agriculture, Ottawa.

Before butterflies, moths, and dragonflies are placed in the box, they should have their wings spread on a board. The insect should be placed on the spreading board on the day on which it was killed and left there for about a week.

J. MINOR STUDY: Birds are useful as well as beautiful.

PROBLEM I: How are birds useful?

Our interest in bird life is not a purely sentimental one. We have learned something of man's unending struggle with his best equipped competitors, the insects. In this conflict, birds are among his most valuable allies. It must be admitted that they do not discriminate between beneficial and injurious insects, but there can be little doubt that the good done far outweighs the evil.



(Courtesy Nat. Mus. of Canada.)

Fig. 159. The bronzed grackle is a handsome fellow, but unfortunately he is a robber of nests.

Hawks and owls are responsible for the annual destruction

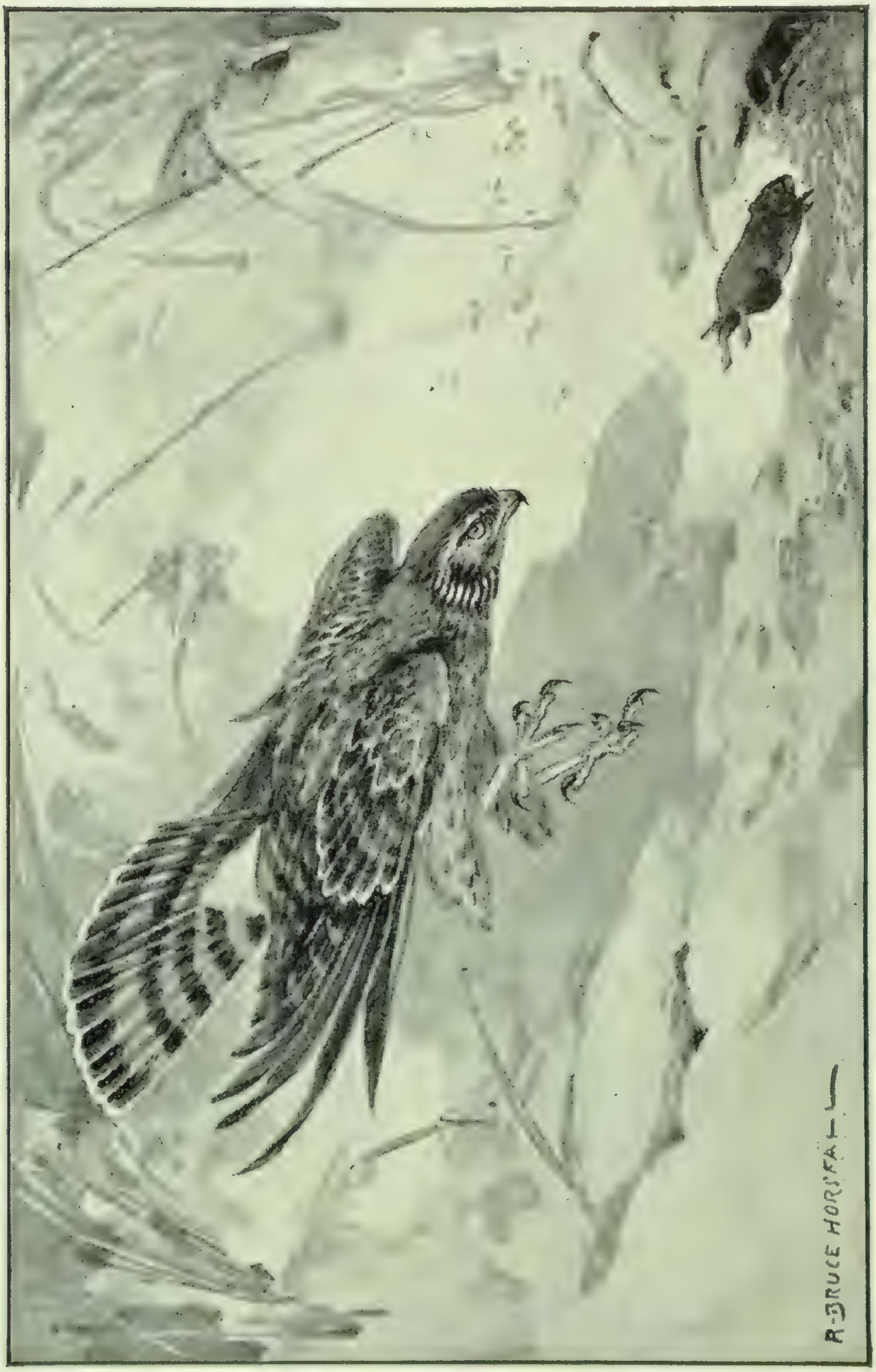
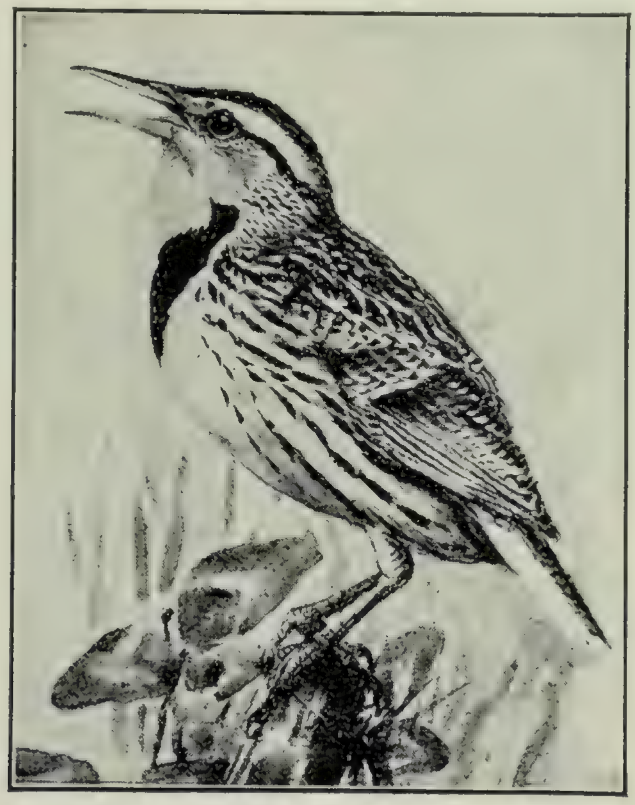


Fig. 160. Will the field mouse escape from the marsh hawk? How do the bill and claws of the hawk fit it for obtaining its livelihood?

of millions of mice and gophers. When we consider the rapidity with which these little animals increase in numbers and the heavy losses caused by them, we regard more highly the value of most hawks and owls.

Birds are of assistance to the farmer in yet another way, for annually they eat vast quantities of weed seeds. Some birds eat offal, and serve as scavengers along the seashore and in primitive countries where modern sanitation does not exist.



(From "Nature Study and Agriculture" by Schmidt, pub. by D. C. Heath.)

Fig. 161. The meadowlark is a bird of much value.

Our poultry, which are the descendants of wild fowl, yield us eggs, meat, and feathers worth many millions of dollars.

Very large colonies of sea birds have made their homes on a number of islands off the Peruvian coast. Their droppings, which accumulate because of lack of rain, are used as a fertilizer called guano after the 'guanaye' one of the birds. Guano, said to be thirty times richer than barnyard manure, has been more valuable than many a rich mineral deposit.

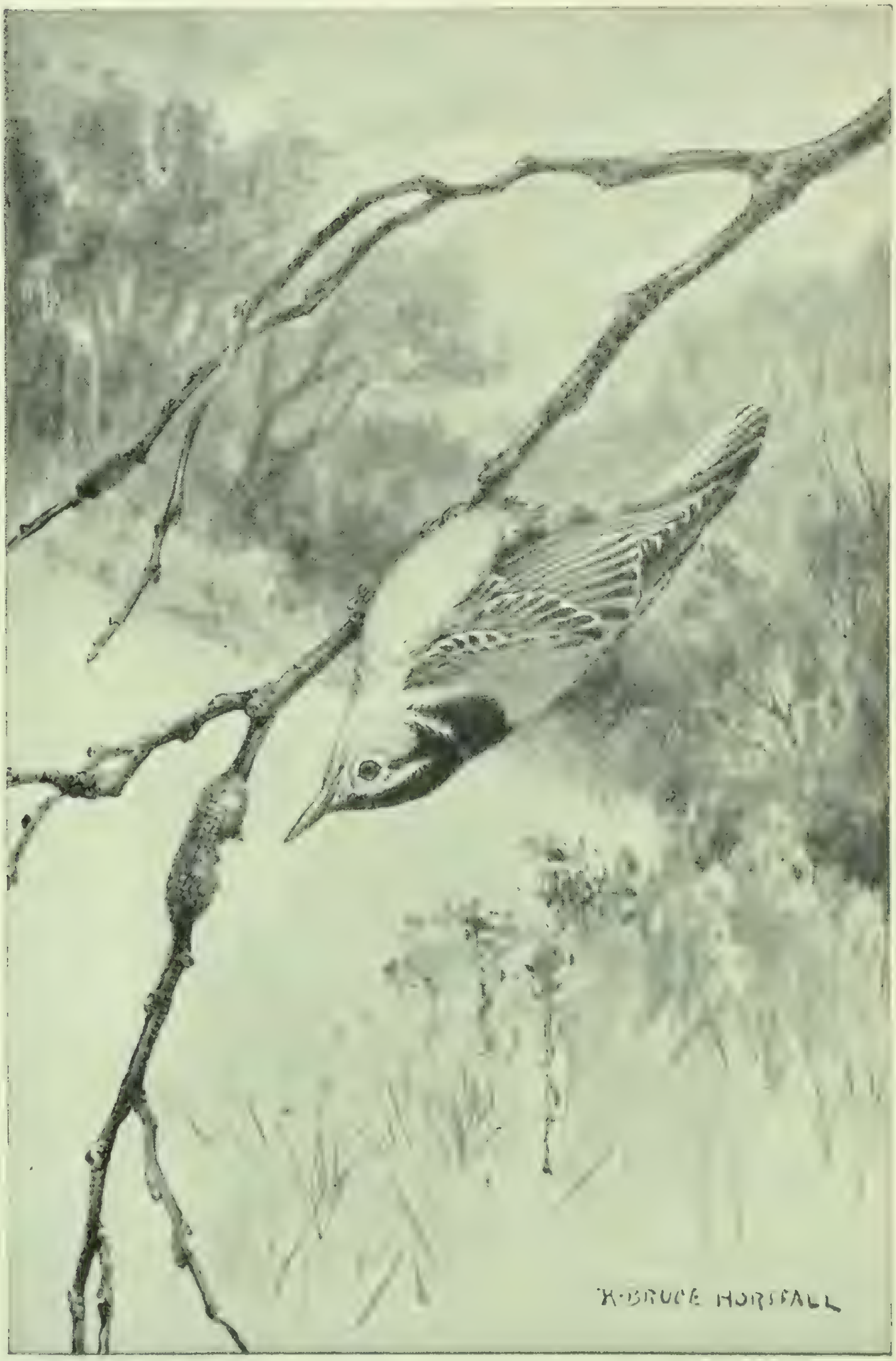


Fig. 162. The white-breasted nuthatch finds that the 'cold storage' eggs of the tent caterpillar moth make a nourishing meal on a winter morning.

Have birds any economic value?

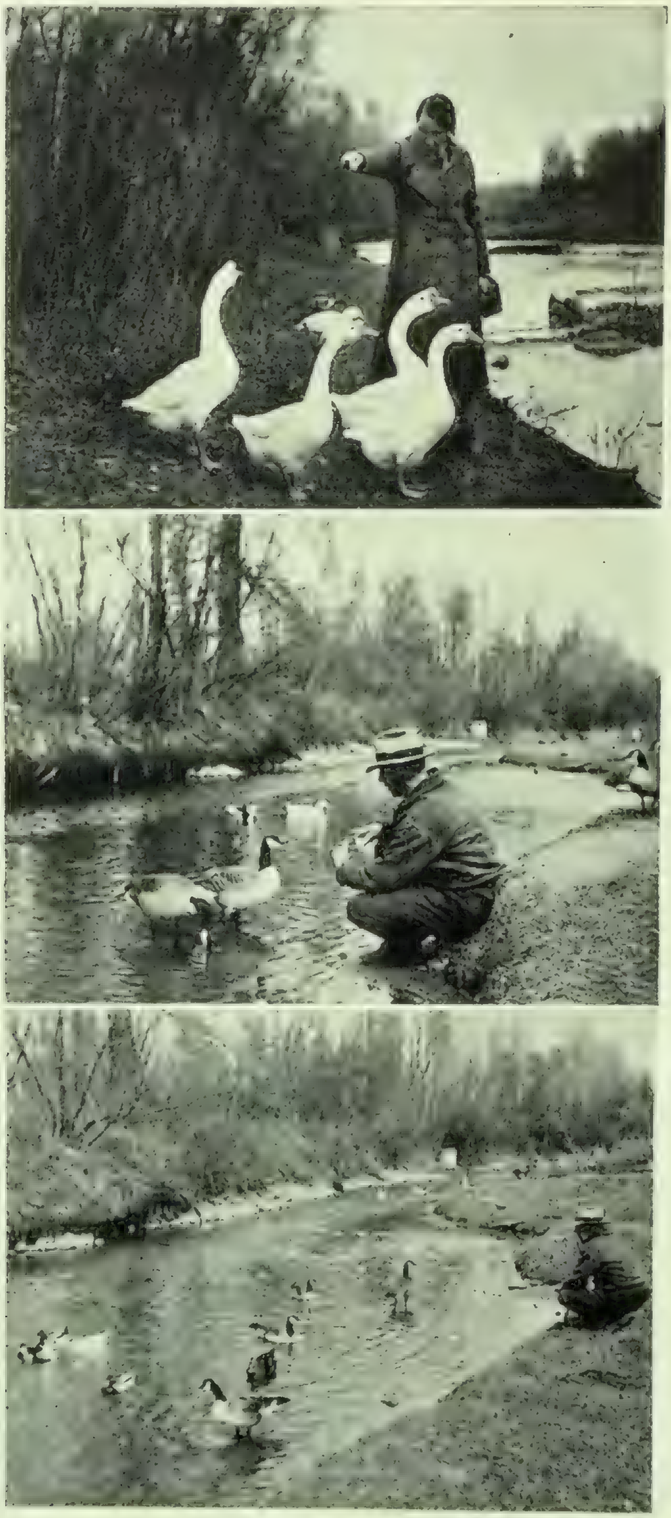
1. *Song sparrows eat over 11,000 tons of weed seeds annually in southern Ontario.*
2. *One meadowlark ate 500 insects and 2,000 weed seeds in a day.*
3. *During the summer months, the birds of Massachusetts eat insects at a rate of 15 carloads a day.*
4. *In one season, a pair of wrens and their young consume about 50,000 insects.*
5. *A chickadee eats from 200 to 500 insects a day.*
6. *The stomach of a flicker was found to contain 28 white grubs.*
7. *In one day, a rose-breasted grosbeak may eat 500 Colorado potato beetles.*
8. *The stomach of a killdeer plover contained 300 mosquito larvae.*
9. *Where a pair of barn owls lived were found 3,100 skulls, mostly of mice and rats.*
10. *In the winter of 1935-36, short-eared owls assembled in the Toronto region to devour numerous meadow mice which were injuring shrubs and young trees.*
11. *During an infestation of field mice in Nevada, gulls, hawks, and owls assisted by other birds, killed 900,000 of the rodents each month.*
12. *Thousands of Franklin gulls invaded grasshopper-infested fields in parts of Saskatchewan and Alberta, and left large areas free from the insects.*

PROBLEM II: Why has man domesticated birds?

Domestication implies that the animal has been placed in a condition of at least semi-captivity, that it is no longer aggressive or bothersome, and that it is willing and able to breed under control.

Wild birds were the most difficult of all animals to capture. They alone, of all animals, are able to fly and thus avoid pursuit.

Man has domesticated many kinds of wild birds. Some have been developed for food; some for their beauty of colour and song; and some, like the parrot, have been trained to speak. The homing instinct of the pigeon has been used to make this bird a carrier of messages.



(Courtesy of W. C. McCalla)

Fig. 163. Wild birds at Inglewood Bird Santuary, Calgary, Alberta.

PROBLEM III: What is the origin of poultry?

The term "poultry" refers to domestic or barnyard birds and includes turkeys, geese, ducks, and chickens. Pigeons also are sometimes classed as poultry. The turkey was domesticated by early settlers in New England. The goose comes from the wild gray goose of central and northern Europe. Domestic ducks are derived from the wild form of Europe

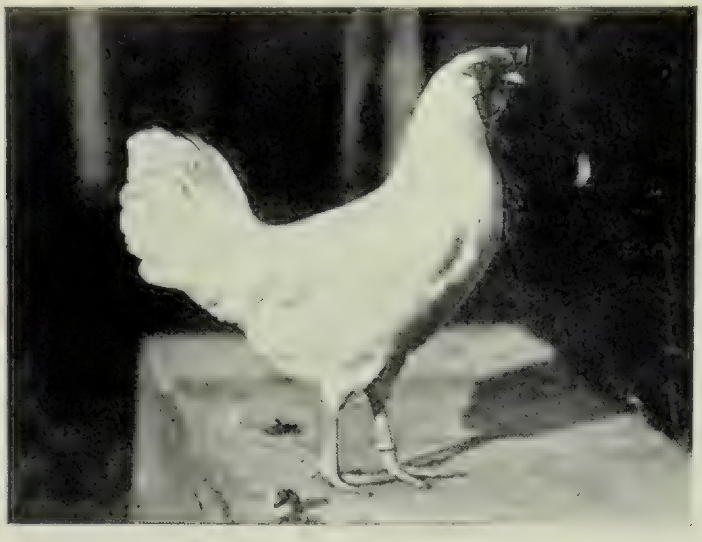


Fig. 164. White Leghorn. An excellent producer of eggs.

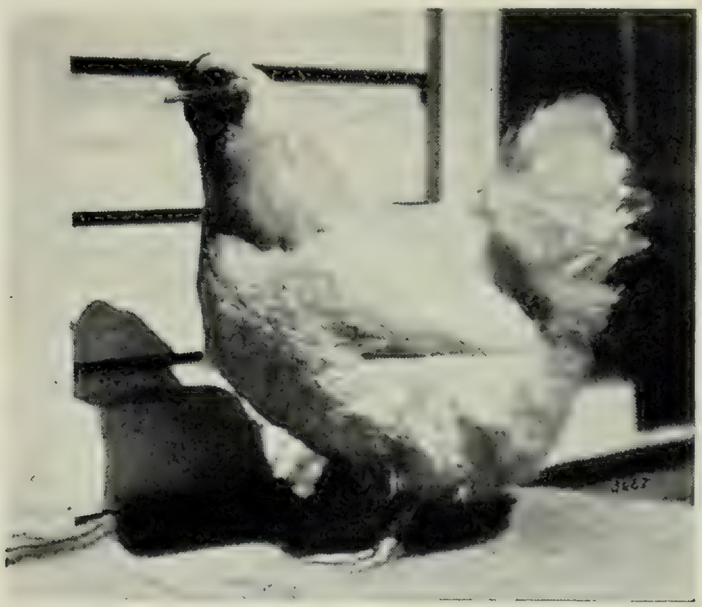


Fig. 165. White Wyandotte. A general purpose bird.

and Asia. All the kinds of hens originated from India jungle fowl. Pigeons are developed from the wild rock-dove still found on some British cliffs.

PROBLEM IV: **What are some of the breeds of chickens?**

The American "Standard of Perfection" recognizes 121 different breeds. Excluding the Bantams, they range in size from 3 to 12 pounds. The breeds are classed under three groups:

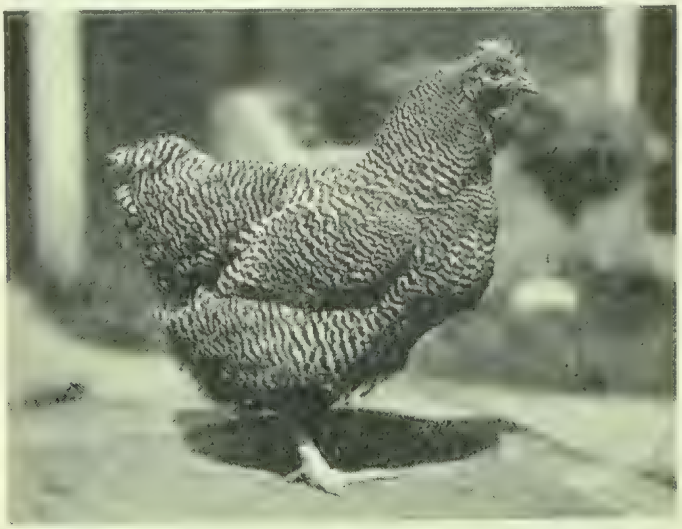


Fig. 166. Barred Plymouth Rock. A popular general purpose bird.

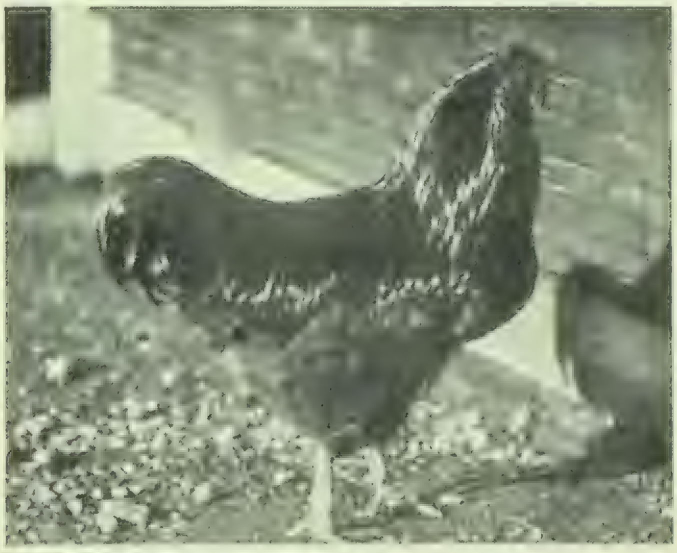


Fig. 167. Rhode Island Red.

Egg	Mediterranean
General purpose	American
Meat	Asiatic

Egg breeds.

The Leghorns and Minorcas are bred mostly for egg production. They are small, active, and nervous in temperament. They have bony, angular bodies adapted for laying a large number of fair-sized eggs. They are good foragers. Because of their large combs, they are sensitive to cold. Their eggs have white shells.

General purpose breeds.

The Plymouth Rocks, Wyandottes, and Rhode Island Reds belong to this class. They are fair producers of eggs and are of good size for table use. They are less active than egg breeds and are not such active foragers. The hens are excellent mothers. These fowl have a yellow skin, and lay brown-shelled eggs.

Meat breeds.

The Brahmas, Cochins, and Langshans are the chief members of this class. They originated in Asia; the Brahmas in the Brahma-Pootra district of India, the Cochins and Langshans in China. They are noted for their unusual size and gentle disposition. They move slowly and are poor foragers. While the egg and utility types are clean-legged, the meat birds have feathered legs.

ENRICHMENT SECTION, NUMBER 8.

Grasshopper menace in 1938.

"In Alberta, the infested area is said to start at a point on the international border immediately south of Cowley. It extends straight north, slightly to the west of Calgary, and as far as Olds, and then branches northwest in a curve through Elnora, Stettler, Meeting Creek to Ryley and then straight east to the Saskatchewan border."

The whole territory within this bounded area is said to be infested in varying degrees with the exception of a small area in a circle which includes Vauxhall, Brooks, Atlee and Medicine Hat.

Exercises:

1. On a map of Alberta locate this infested area and within it the non-infested area.
2. Watch for articles on grasshopper or cricket invasion of Alberta. Keep your map up to date by changing the boundary of the infested area as new information makes such changes necessary.
3. Discuss methods used in an attempt to control (1) grasshoppers, (2) crickets.

TOPIC V—THE EARTH'S CRUST

The solid earth, like the air and ocean, is of great importance to man. It furnishes him with a home. Nearly all of it is covered with a mantle of soil, in which food-plants and other vegetation grow. Everywhere beneath the soil is found solid bed-rock, from which many valuable mineral substances are obtained.

UNIT 8. MAJOR STUDY: The earth's crust provides a home for living things.

A. MINOR STUDY: Man has held many beliefs about the origin of the earth.

PROBLEM I: How did man learn earth science?

For centuries, men took the earth as a matter of course and made no attempt to delve into the origin of things. They believed that every object was endowed with life and was friendly or unfriendly to man. Mediators, such as priests, were necessary to keep unseen forces friendly. It is not to be wondered at that they regarded the sun and other heavenly bodies as objects worthy of worship.

Many conceptions of the earth come down to us from these early ages. Some thought of the earth as a flat disk that either floated in water or was supported on pillars; others regarded it as a two-storied structure with windows in the roof through which the waters that surrounded the firmament could reach the earth. Anaximander, a Greek, who lived about 550 B.C., believed that all matter was composed of one basic substance, water. Water rarefied was fire; condensed was earth. About the same time, Pythagoras thought that there were four elements—earth, water, air, and fire.

Although some people still insist that the earth is a flat disk, from the time of Pythagoras, it has been looked upon as a sphere whose rotation explained the apparent rotations of the heavens. Claudius Ptolemy, a Greek, (127-151 A.D.)

placed the earth at the centre of the universe with the fixed stars fastened to the inside of a vast dome which rotated once every twenty-four hours. This earth-centered universe was accepted for thirteen hundred years.

Copernicus (1473-1543) corrected this conception and placed the sun at the centre of the solar system with the planets rotating around it. He taught that the moon rotates around the earth; that the earth turns on its axis from the west to east, thus accounting for day and night and the apparent motion of the stars.

In 1630, Galileo constructed a telescope and by observing heavenly bodies, established the truth of the Copernican theory.

More than a hundred years later Sir Isaac Newton built the first reflecting telescope. His discoveries laid the foundation for modern scientific study of the universe.

PROBLEM II: **Where did the earth come from?**

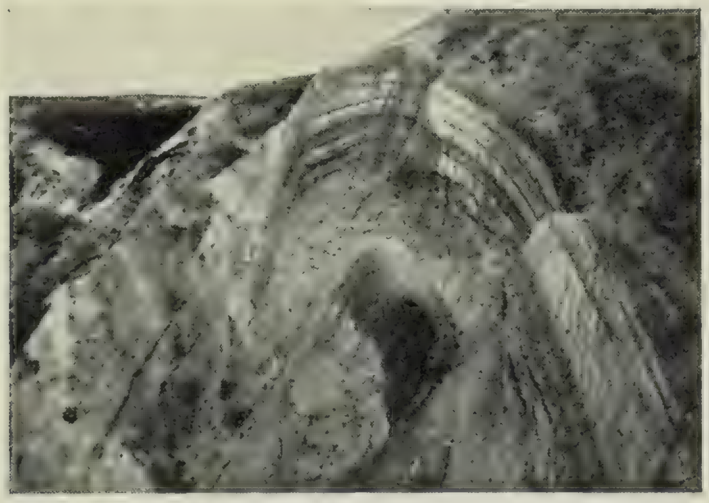
Following the examples of such thinkers as Kepler, Galileo, and Newton, men began to explore the universe and to attempt to read its story. We must remember that we are dealing with theories, not facts, and are speaking first and not last words. The most likely theory follows:

To-day, it is believed that the planet on which we live was once part of the intensely hot gases which make up the outer region of the sun. Just as the moon and sun raise the seas into tides, so some huge star passing close to the sun caused vast gaseous tides. Some of this material separated from the rest, and held by the attraction of the greater remaining portion swung around it. Like a rain-drop or a speck of mercury, this great mass of substance became globular in form. Gradually it cooled, first becoming liquid just as steam changes to water. Heavy liquids, largely molten iron, sank to the centre. (It is believed that the great core of the earth, nearly 2,000 miles in radius, is in the main composed of this metal.) On this solidifying core rested lighter liquids containing some iron. Last to remain in liquid form was the "crust" which eventually cooled to form very hot rock about 36 miles in depth.

Despite the heat due to pressure, the earth's rocks have remained solid except in spots where the weight upon the interior was not so great. Here the rocks turned to liquid and these liquids melted a way upwards just as hot water melts ice. Sometimes they met barriers they could not pass; but where the crust was not so dense, they made holes and poured forth as lava (basalt). This lava is heavier than the crust of the earth and after it had spread until it covered a great area, the crust began to sink. When it stopped, ocean beds had been formed. (Every ocean bed has a floor of basalt.)

The earth's water came either from within or without the earth. The air was not as we know it to-day. Human life did not become possible until green plants provided oxygen in sufficient quantities to sustain life.

There now existed one great continent penetrated by long fingers of water. Far below the surface, the rocks under great pressure were solid, but plastic enough so that harder rock that would not melt at so low a temperature could move very slowly through them. The continents slid away through this plastic sea. When resistance was met, lighter rocks were forced upwards and formed mountains. As North and South America were forced westward due to the rotation of the earth, the thick basalt floor of the Pacific Ocean was en-



(Courtesy of Geol. Survey of Canada.)

Fig. 168. Folded beds in Mud Buttes, Alberta.

countered, and because of the pressure from behind, the Rocky Mountains and the Andes chain were forced upward on the west side. Islands were formed when they did not keep up with the land masses when the continents migrated.

Other changes are taking place in the earth's crust because of various forces that are at work. As the crust cools, contraction takes place. Because of the erosion of its lands, high spots are being worn down and low spots are being built up. These inequalities create strain, and earth movements, such as upheavals or subsidences, equalize the forces again that are at work.

Exercises:

1. Have you ever watched ice form a jam on a river or lake, when some obstruction stops its onward movement? Describe what takes place.
2. If you travel through the Rocky Mountains, note the evidence of crustal shortening, and note also the steep fronts to the west and the long slopes to the east. Make drawings to illustrate this phenomenon.
3. Cut out pictures of mountains, particularly those showing strata. Paste these in your scrapbook.

B. MINOR STUDY: Man's mode of living is tremendously influenced by the character of the land on which he establishes his home.

PROBLEM I: What are the occupations of dwellers by the sea?

Those who dwell by the sea on a rocky, infertile coast must seek their livelihood on the water. Where the land bordering the water is suited to agriculture, men will supplement the harvest of one by that of the other. When the hinterland is prosperous, densely populated by those with goods to sell and wants to satisfy, ports are a necessity and cities spring up on estuaries and inlets where large ships may safely enter.

PROBLEM II: What are the occupations of dwellers in valleys?

The rural dwellers in valleys where the soil is deep and rich are farmers whose fields yield bountiful harvest and whose fruit trees bear abundantly. We think of the Okanagan Valley in British Columbia, the Annapolis Valley in Nova Scotia, world famous as fruit growing districts, and of the fertile basins of rivers such as the Fraser in British Columbia or the North Saskatchewan in Alberta. It is no accident that river valleys have been the birth place of ancient civilizations.

PROBLEM III: What are the occupations of plain dwellers?

In early times, the plains dweller was a herdsman. Where rainfall was scanty, it was necessary to move from one area of grassland to another, a way of living ill-suited to the sowing and harvesting of crops and to the possession of permanent dwellings, and the gathering together of household goods. Even to-day there are pastoral peoples in Asia, Lapps of the tundras, Khirgis of the steppes of central Asia, Bedouins of the Arabian Desert. Where European races settled upon grasslands—as a rule, the more productive regions—in North America, the Argentine Republic, South Africa, and Australia, they selected suitable sites and built houses. Over vast areas grain crops have replaced the original pasturage. In some places, grain crops have been supplemented by the raising of various forms of livestock such as cattle and horses. This is known as mixed farming. In places of scanty rainfall, irrigation is often practised, and there we find such crops as sugar beets, alfalfa, and wheat. On irrigated land around Brooks, Alberta, are grown fruits that find a ready market in Calgary.

PROBLEM IV: What are the occupations of forest dwellers?

Dense forests exert a powerful influence on the lives of those who dwell within them or in their vicinity. Our pioneer fathers followed the explorer into the heavily timbered areas of Canada. They built log houses, and after they had cut down the trees, they had "log rollings" when the neighbours came to help. The logs were rolled into great heaps and burned.

These pioneers were alert to danger. We still read of forest fires sweeping over some lonely settlement, leaving desolation

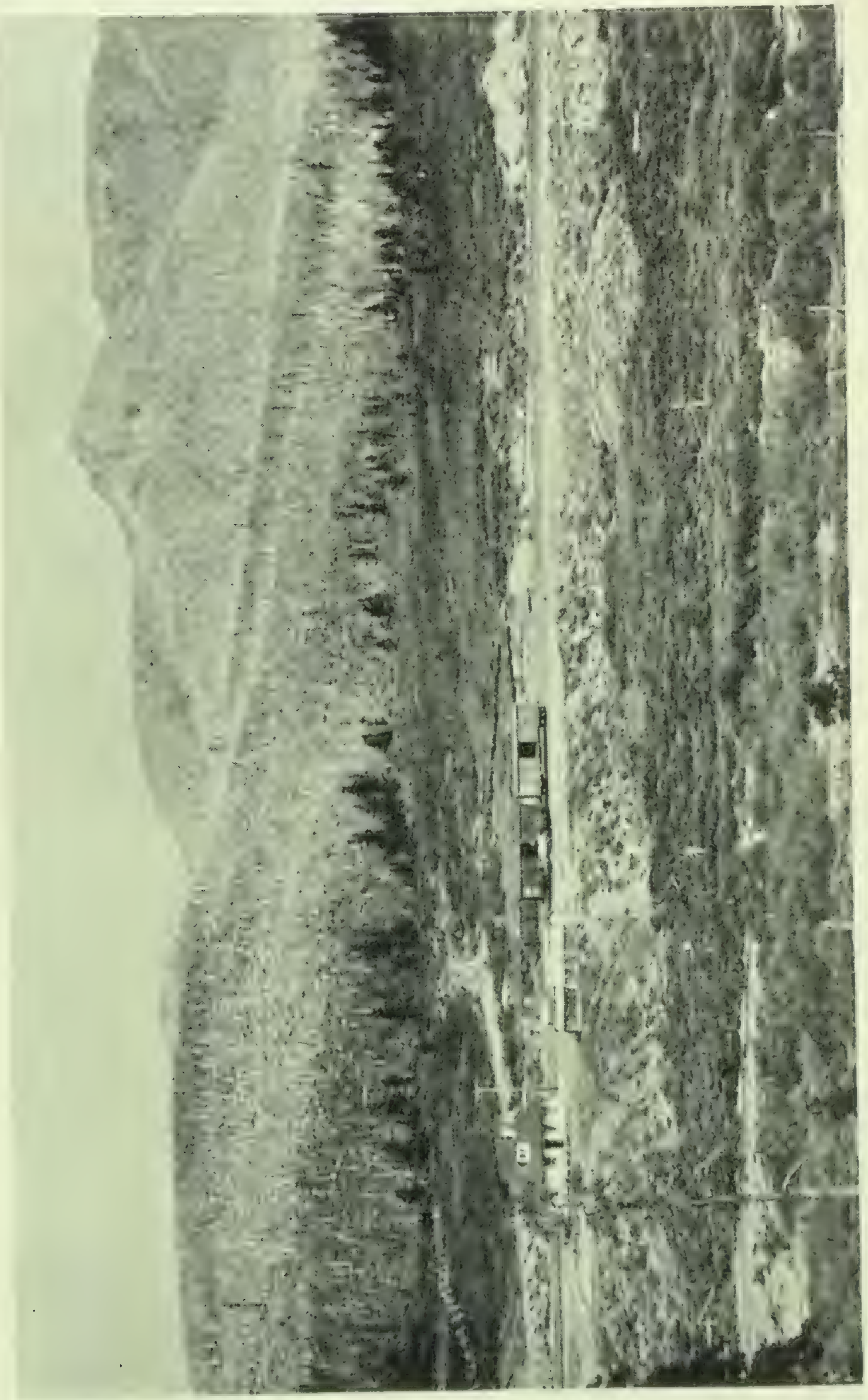


Fig. 169. The railway runs through a lonely mountain settlement.

and ruin in their wake. There was also a constant danger from wild animals. These settlers developed a keen sense of direction since they could not see great distances.

The lumbering industry began with the supplies most accessible to these early settlements and progressed inland along the great water highways as did the settlement of the country. The click of the axe, as trees were felled in the forest, was soon replaced by the whir of the circular-saw. The logs were cut into lumber at the sawmill. This lumber was shipped to various parts of the country for the construction of homes, stores, industrial plants, sidewalks and bridges.

Forests provide shelter for game animals and streams for fishing, and are delightful places in which to spend a vacation.

PROBLEM V: What are the occupations of mountain dwellers?

Mountains have always been looked upon as barriers to civilization. Those of us who saw the motion picture "The Silent Barrier," will appreciate the gigantic task that men accomplished when they laid the tracks of the Canadian Pacific Railway through the passes and river valleys of the Rocky Mountains.

The valleys and lower side-slopes may be farmed for a variety of crops. Some of our finest fruit comes from the Okanagan Valley in British Columbia. From the upper slopes timber is cut.

Alberta is very fortunate in having two wonderful mountain resorts at Banff and Jasper. Thousands of tourists from all over the world visit these national parks yearly. With wonderful facilities for winter sports, Banff may truly be called the "Switzerland of America."

C. MINOR STUDY: The earth's crust is in slow movement: the outlines of the lands and oceans are ever changing.

Of the total area of the earth, about one-fourth is land, and two-thirds of this land is in the Northern Hemisphere. The continents are clustered around the north polar regions with tongues projecting southward. They are characteristically triangular in shape and taper southward.

The land surface of the earth is irregular, the greatest distance from ocean floor to mountain top being some 60,000 feet. Between these extremes are found a wide variety of relief features, the most important of which may be classified as plains, plateaus and mountains. Plains are the low, level lands of the earth. They are 'low' and 'level' only in comparison with their surroundings. Plateaus are high in comparison with their surroundings and have numerous summit areas. Mountains rise sharply above their surroundings and have small summit areas.

Fig. 170.

PROBLEM I: What agencies are changing the form of land?

The form of land is constantly undergoing change through the work of many agencies. Among the more important of these are winds, water, ice, crustal movements and volcanoes.

PROBLEM II: How do the winds sculpture the earth's surface?

Air in motion is a powerful agent in transporting soil from one area to another. In the west of both Canada and the United States the soil was protected originally by grasses and shrubs from erosion by wind. Then the white man ploughed the prairie sod and planted his crops. The fibrous roots that formerly bound the soil particles together decayed; because of the practice of summer fallowing there was no longer a continuous sheltering of the soil by a cloak of vegetation. When prolonged drought came, hundreds of millions of tons of the loose, dry top-soil were carried away. What feelings of helplessness and dismay must fill those who see their means of support borne off by the wind!

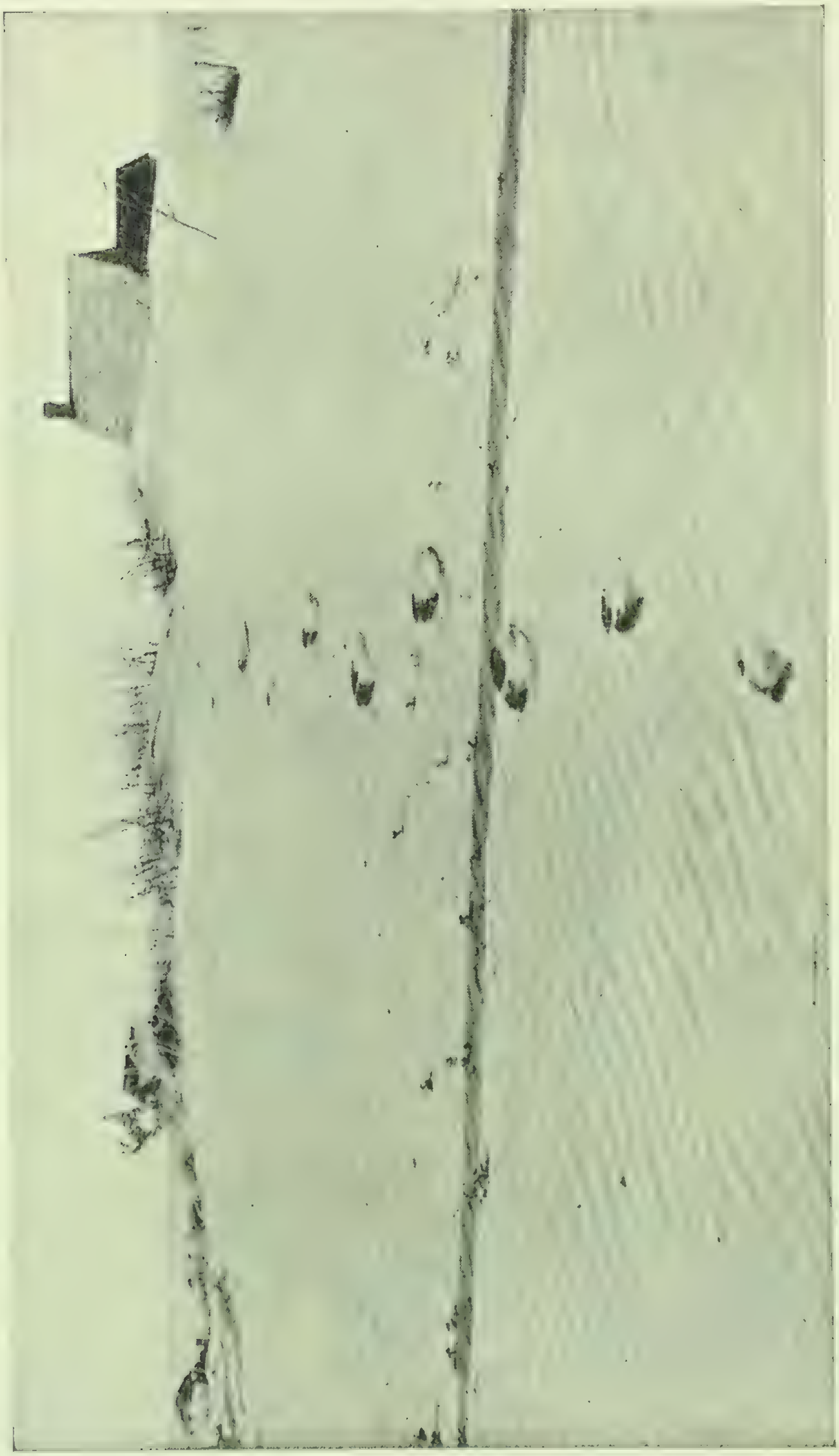
There is another side to be considered. Large areas of land owe their fertility to soil transported by wind from other regions. This loess, as the wind-borne soil is called, is found in Iowa, Kansas and Nebraska and also in the valleys of the Rhine, Rhone and Danube. The deep, yellow, fertile soil of northern China is loess which has been carried from what is now the Desert of Gobi.

By themselves, winds have little effect in reducing rock to soil. However, just as a sand-blast is effective in etching glass or cleaning stone buildings so wind-driven sand sculptures exposed rock.

By swaying or uprooting trees growing on a cliff, winds cause the splitting and dislodgment of rocks.

In parts of Alberta and Saskatchewan and in many other places, the wind causes a loss of agricultural land by burying it under sand. Ridges or dunes are built up and, year after year, move slowly forward. It is possible to arrest this movement by planting suitable grasses or trees the roots

Fig. 171. Snow fence in Alberta.



(Courtesy of the Dominion Dept. of Agr.)

Fig. 172. Soil from other farms has drifted here to a depth of three or four feet.

of which help to prevent the sand particles from drifting.

ENRICHMENT SECTION, NUMBER 9.

$192,000 per section cost when one inch of soil drifts.

The following figures were compiled by Dr. F. A. Wyatt, professor of soils, University of Alberta, to show the wastage of farm lands in western Canada, and the urgent need for measures to combat wind erosion.

It would require $150 to $250 worth of commercial fertilizers to replace the nitrogen, and $40 to $50 worth to replace the phosphorus lost by the removal of a layer of soil one inch deep over one acre Nitrogen and phosphorus are valuable plant foods.

One inch of soil over an acre weighs about 156 tons. It contains 300 pounds of phosphorus, 1,500 pounds of nitrogen, and 15 tons of organic matter. According to one estimate, a cubic mile of lower air during a dust storm contains 225 tons of fine soil.

Exercises:

1. In your scrapbook paste articles on soil erosion by wind.
2. List the various methods advocated by agricultural authorities to prevent soil drifting.
3. On a map of North America locate the territory known as the "Dust Bowl."

PROBLEM III: How does water assist in altering the earth's surface?

Rain-wash.

If we walk along a gravel road on a rainy day, we see hundreds of streamlets each carrying a load of sediment. When the rain is over, we may observe the channels cut by the water and, here and there, little sandbanks where the washed-out material was deposited.

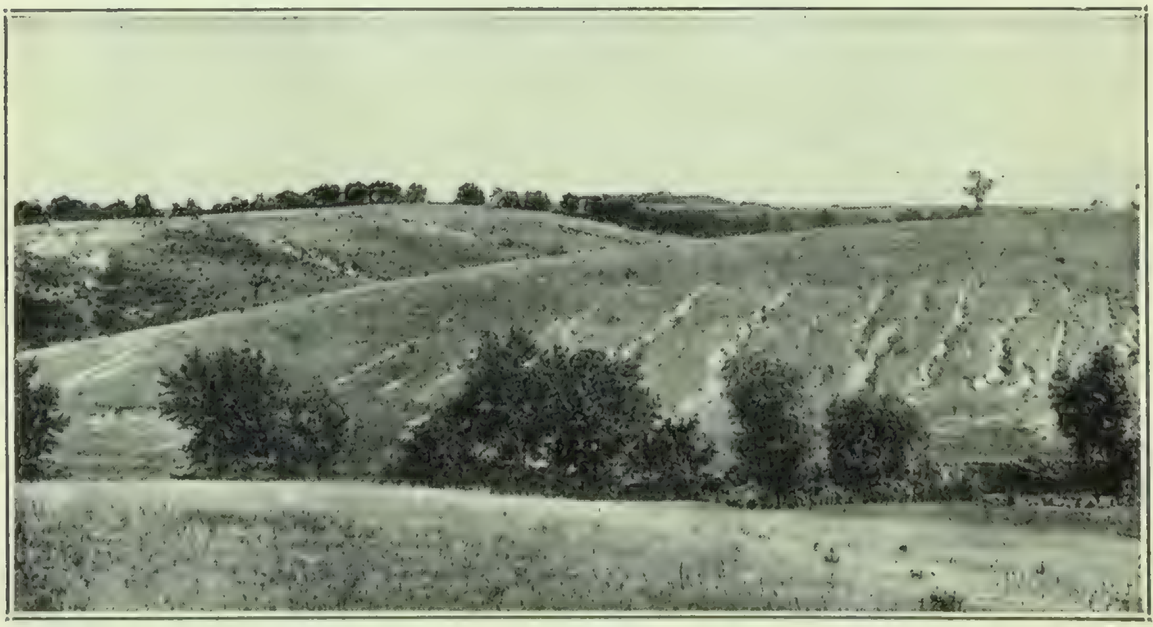
To those who are not directly concerned with the upkeep of the road this may appear a rather trivial matter. Yet, if we consider the effect of rain-wash over a large area, and during long periods of time, we are impressed with the considerable changes that may be brought about.

The seven inches of soil between us and starvation.

In a quarry or railway cutting a rather curious fact may be observed. The layer of soil nearest the surface is darker than the underlying material. This dark colour is due to decaying vegetable matter such as roots and leaves. We may regard the top soil, as it is called, with more than ordinary interest because on it our agriculture depends. The average depth of this fertile layer in uplands is estimated at about seven inches.

The removal of top soil by water.

The effect of rain-wash is very evident on hills which have been stripped of their cover of trees. The leafy screen that broke the force of the rain is no longer there, and the porous mould which absorbed much of the water is borne away, and not replaced. Unless we re-plant the hills with trees or clothe them with grasses to bind the soil with their matted roots, in a few years nothing will remain but a sparse and stunted



(Courtesy of the Missouri College of Agriculture.)

Fig. 173. Valuable soil has been washed away from this field.

vegetation struggling to exist on the almost bald rock. It should not be thought that erosion (Lat. *rodere,* to gnaw) occurs only on slopes which once were wooded. In humid regions, soil may be eroded from any sloping field temporarily or permanently deprived of its protective cover of plants.

After heavy rain, we may notice on cultivated land little channels formed by the 'run off' or water which does not soak into the soil. These miniature ditches are known as 'finger' or 'shoe string' gullies. Should one of them become deeper and deeper, as frequently happens, a formidable gully is developed, and great quantities of valuable top soil are borne away. When the top layer vanishes, the less valuable subsoil is carried by water from the gully and deposited on low-lying fertile land. This burial of rich soil under an infertile layer results in further loss to the farmer.

Because gullies are very noticeable, most people think that their formation is the most serious effect of water on sloping

Some statistics on erosion by water.

In the United States in 1910 the area of land totally ruined by erosion and abandoned was 10,000,000 acres.

In 1935 the area was 35,000,000 to 50,000,000 acres.

Acreage of land in the United States in 1935 with more than three-quarters of its top-soil lost, 192,000,000. (This is 10 per cent of the area of the United States, exclusive of water and large cities.)

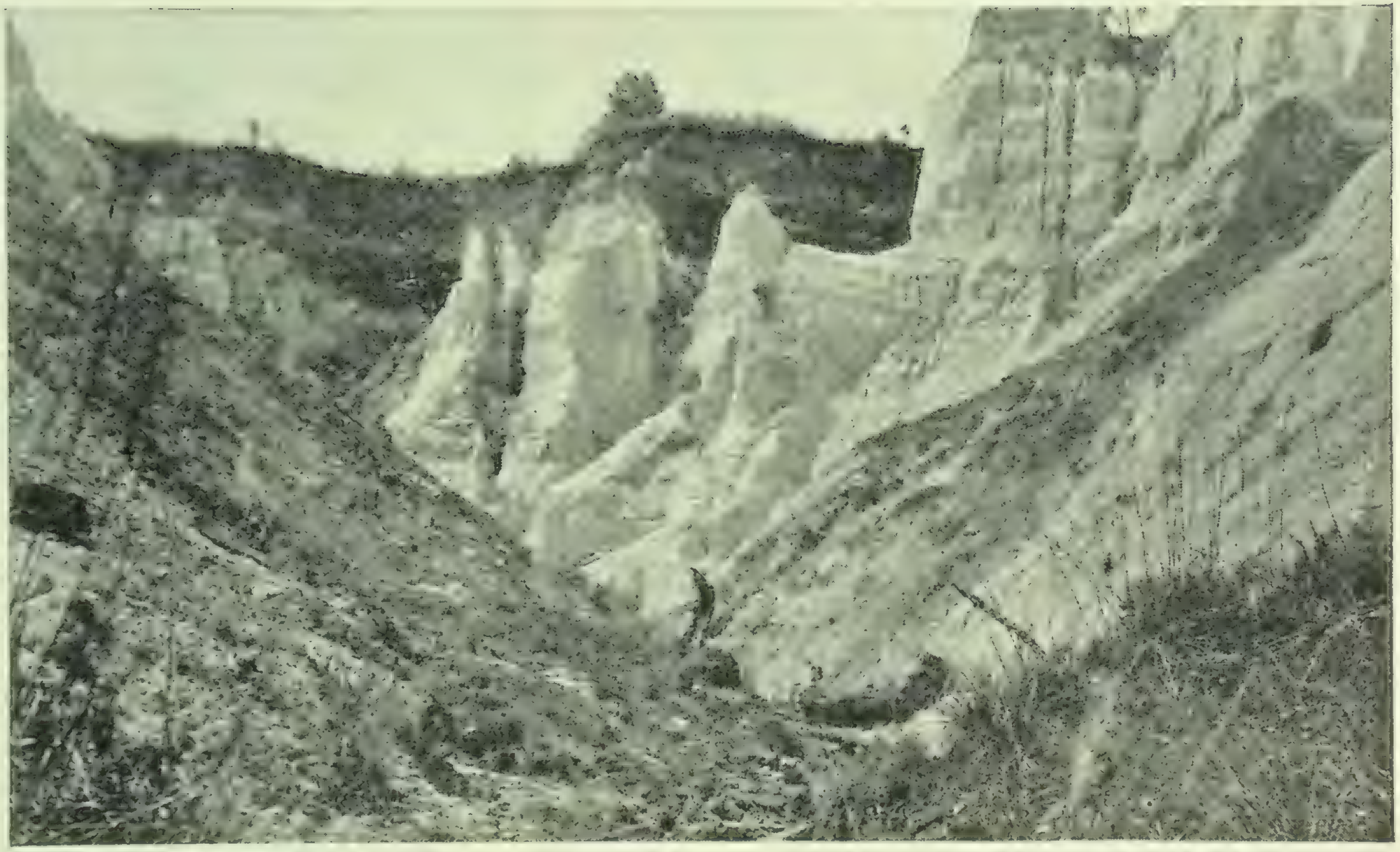
Dissolved plant food carried annually to the sea by rivers of the United States amounts to 63,000,000 tons. (The corn crop of the U.S.A. takes only 3,000,000 tons of plant food from the soil each year.)

Since the settlement of Missouri, water has carried from that state 26,000,000 tons of nitrogen, 13,000,000 tons of phosphorus, and 300,000,000 tons of potassium.

In one South Carolina county, gullies have destroyed 90,000 acres of formerly fertile land.

Estimated annual loss caused by erosion in the U.S.A. is $400,000,000.

NOTE: Figures for Canada are not available.



(Courtesy of Caterpillar Tractor Co.)

Fig. 174. This gully in the State of Georgia varies in depth from 125 to 200 feet; at places it is over a mile in width. In its course, which extends over two counties, it has ruined 50,000 acres of land. It is believed that the gully was started about 70 years ago by water dripping from the roof of a barn.

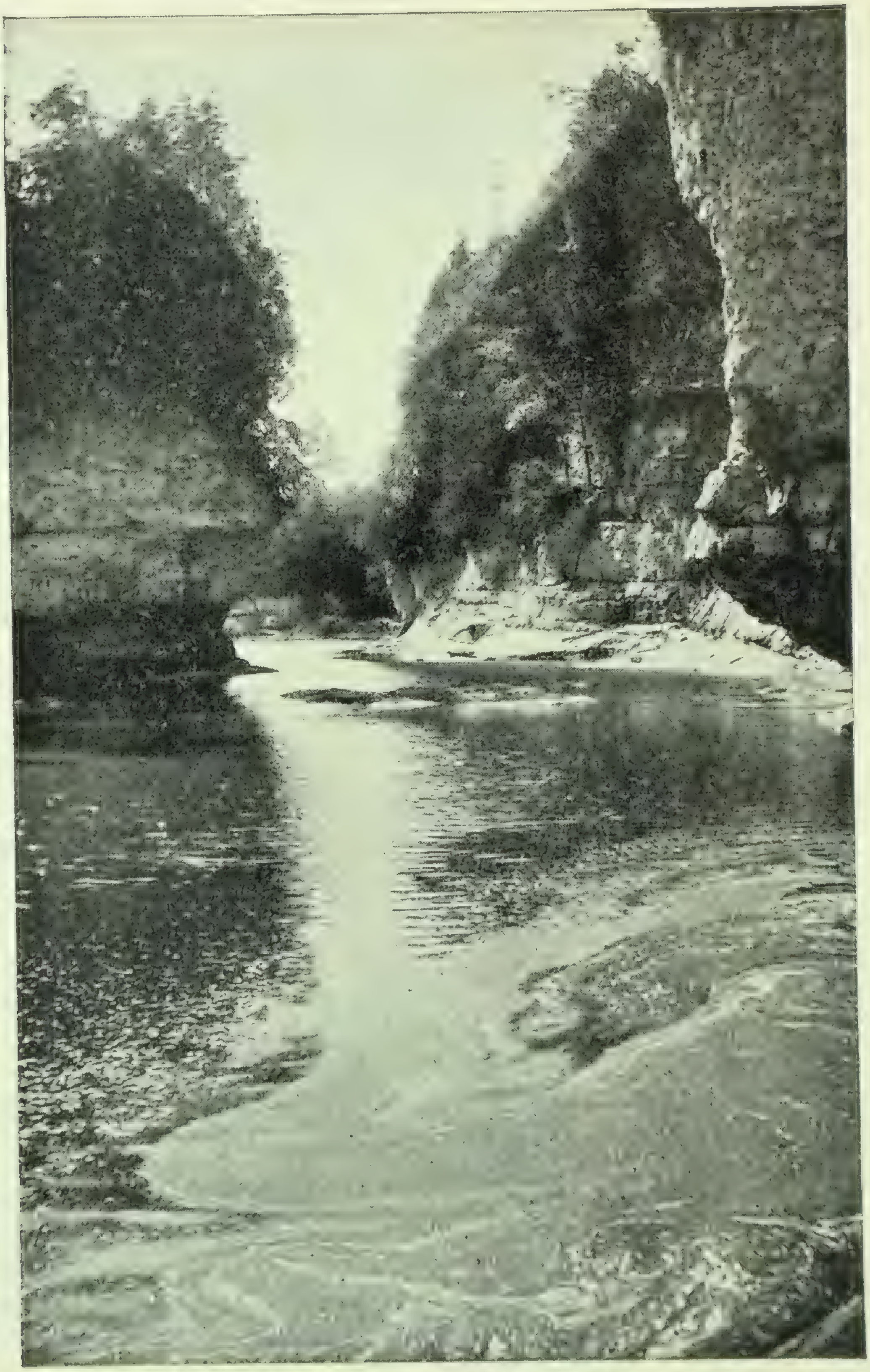
land. However, there is a less noticeable but much more wasteful action. After rain has fallen for a time on a slope which lacks protective vegetation, the water often runs away, not in channels, but in a sheet, bearing with it a thin layer of the richest soil. This unobserved robbery is called sheet erosion.

PROBLEM III. (a): **How do rivers erode their banks and beds?**

Many of you have seen a river flowing between walls of rock. During thousands of years the channel was gradually deepened by the running water. By itself, water is an exceedingly slow agent in the wearing down or erosion of rock, but the presence of moving pebbles and sand hastens the process by friction. Indeed, the work of streams in carving out their courses with the aid of fragments in motion is similar to the effect of sandpaper on wood. As the pebbles rub against each other and against the river bed, they are smoothed and rounded. They become smaller and smaller and so are moved more easily. By stages the rock particles are brought down the river. Some are dropped at places of slow current; some finally reach the river's mouth.

Not only do rivers scour their beds, but also they erode their banks. The rate at which the banks are cut is often very marked at places where the stream changes its direction.

The following estimates enable us to gauge the importance of rivers as eroding agents and transporters of soil. Annually, the rivers of North America carry seaward a quantity of sediment equivalent to one foot over the whole continent. Each year, the Mississippi rolls 40,000,000 tons of sand along its bed to the sea. In addition, there are 340,000,000 tons of finer material suspended in its water. The Ganges carries to the sea about 1,000,000 tons of material every day, but even this large amount is only a third of the sediment brought by the Yangtze or Blue River of China. It is well to remember, however, that each tributary streamlet, each tiny rill of an hour's duration contributes to the reduction of rocks to particles, the wearing down of the uplands, and the trans-



(Courtesy of Geol. Survey of Canada.)

Fig. 175. Canyon of the Grand River at Elora, Ont.

portation of fragments to land of lower level. No figures are available for rivers in Alberta.

PROBLEM III. (b): **How does man try to prevent erosion by water?**

No general remedy for erosion by water can be given, for much depends upon the slope and the kind of soil.

On gentle slopes, the ploughing should be done in contour lines, that is to say, at right angles to the direction of the slope. The furrows serve as little terraces and reduce the quantity of soil washed away.

When moderate slopes are cultivated, it is advisable to construct terraces as well as to plough the land in contours.

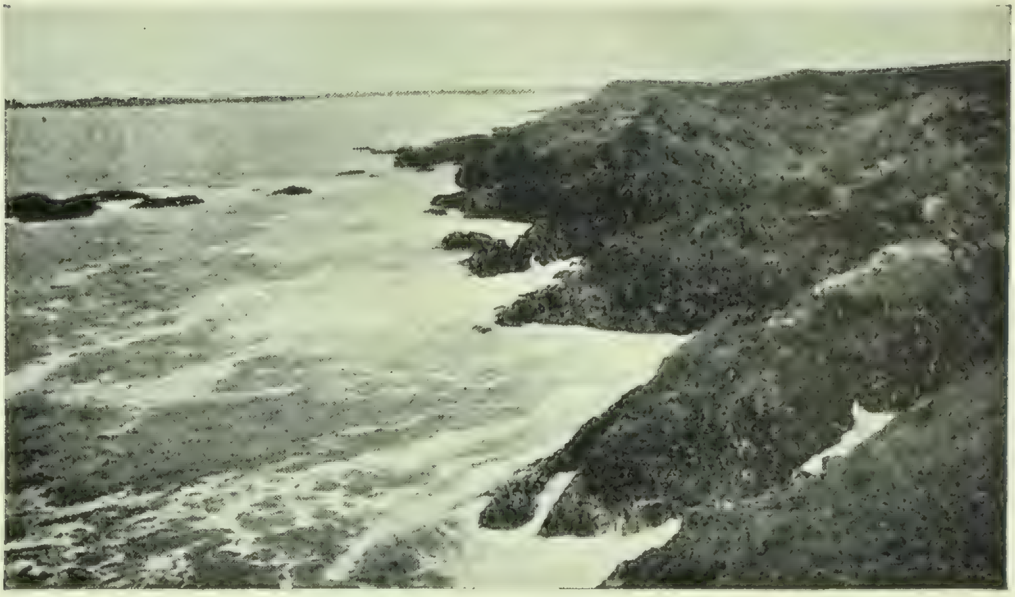
Steep slopes should not be cultivated but should be left with a permanent cover of grass or trees.

In short, the following plans are adopted for slopes ranging from those that are gentle to those that are quite steep: (1) contour ploughing; (2) contour ploughing and terracing; (3) the growing of grass and legumes such as clover and alfalfa for moderate grazing and for hay; (4) the growing of grass and legumes for hay only; (5) the planting of trees.

PROBLEM III. (c): **Is water a builder as well as a destroyer?**

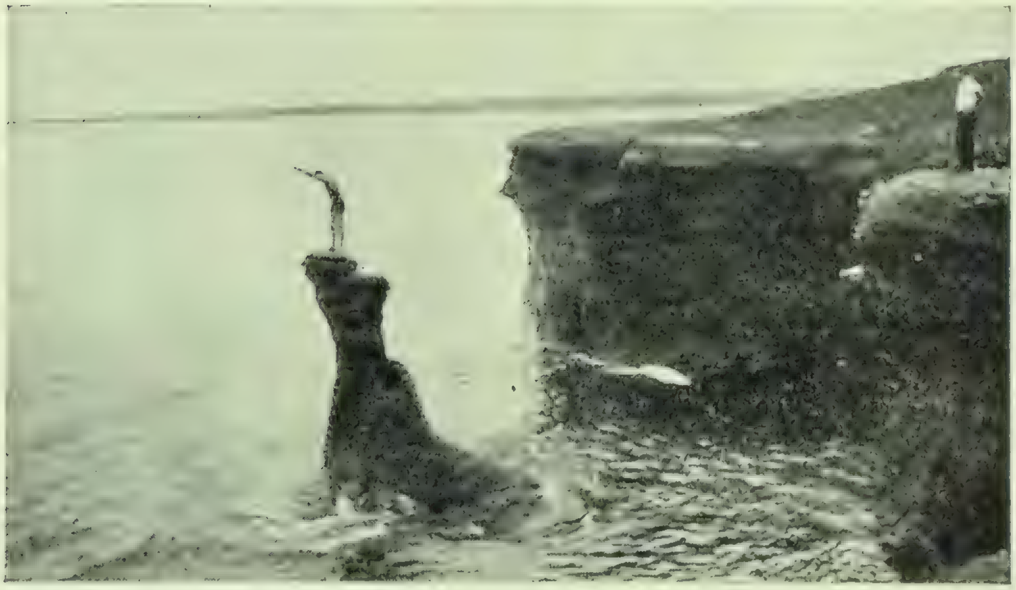
Great rivers and little brooks alike spread over their flood plains the silty wreckage of the rocks. New land is built up yearly at the mouths of many great rivers from soil torn from the highlands. Where the Mississippi enters the Gulf of Mexico, mud flats are annually extended a distance of 300 yards, a process which during the past ages brought into existence Louisiana and a considerable part of Alabama. The Adriatic Sea is being filled rapidly with the wastage of the Alps, borne by the Po, the Adige, and other rivers of northern Italy. Towns which the Romans knew as ports are now miles inland.

When a river on reaching a sea or lake deposits great quantities of sediment, it cuts for itself many channels or distributaries through the soft mud. An intricate network is formed the pattern of which changes in every flood. The



(*Courtesy of Geol. Survey of Canada.*)

Fig. 176. Waves gnawing a rock-bound coast in Nova Scotia.



(*Courtesy Geol. Survey of Canada*).

Fig. 177. The diver is poised on a remnant of the old coast-line.

islands formed by the channels are often roughly fan-shaped. Their resemblance to the Greek letter, capital delta (△), has caused the name to be given to an area where the river enters the sea by a number of mouths. Examples of Canadian deltas are those of the Mackenzie and the St. Clair rivers.

The fine sediment deposited by rivers, along their banks in times of flood or at their mouths, is generally of high fertility, so that, where the climate is suitable, there is usually a very dense population. In this connection we think of the delta and valley of the Nile and the deltas of the Rhine, the Po, the Ganges-Brahmaputra, and the Hwang-ho or Yellow River.

Unfortunately, delta regions are at times covered by terrible floods. Cities built in these areas, for instance New Orleans, have special difficulties in drainage and disposal of sewage since the level of the streets is seldom above, and frequently much below, that of the river.

At places, the coast yields slowly but surely to the unceasing assault of the waves. The shore-line recedes, dwellings are abandoned, and ships sail where ancient seaports flourished. Within historic times, Heligoland, an island in the North Sea belonging to Germany, has been reduced by the erosion of waves to a mere fraction of its former area.

Field work.

(i) How does the soil found at the mouth of a woodchuck's burrow differ from the surface soil?

(ii) Look for examples of erosion by water and bring a report to class.

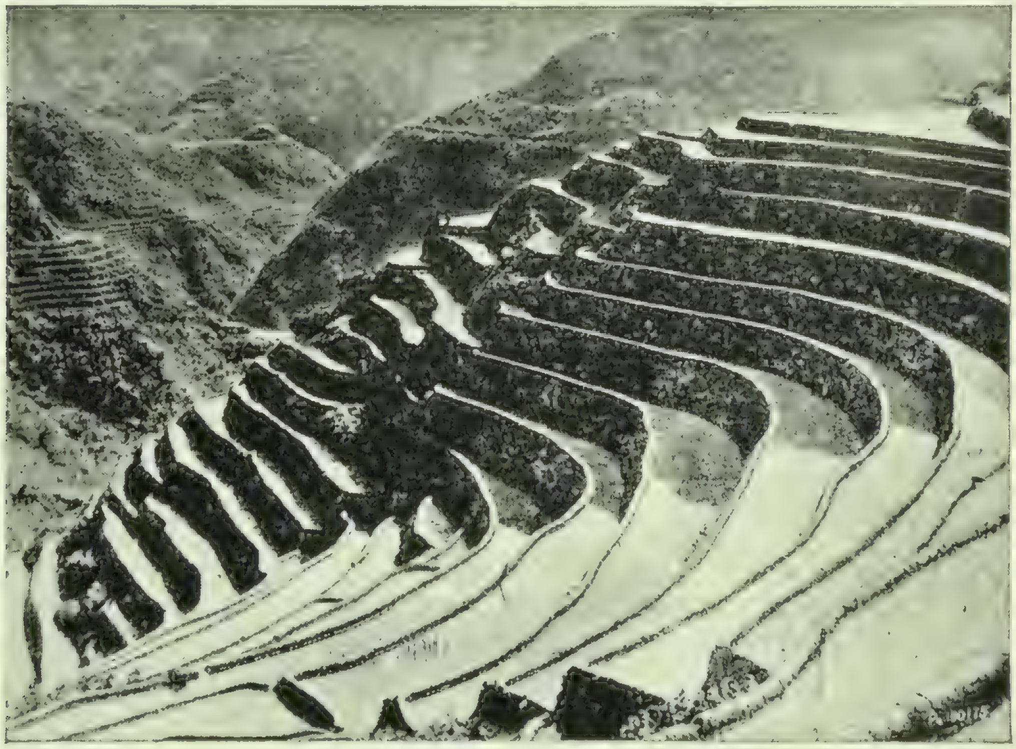
(iii) If you find trees in their original position but with their roots more or less exposed, what conclusion may be drawn?

(iv) Compare the depths of fertile soil at the bottom and on the side of a hilly field. If some of the rich soil remains on the slope, will the lower land be rendered more or less fertile by erosion? If the sub-soil is exposed on the side, how will the lower land be affected?

(v) Examine one of the little banks of sand deposited along the sides of roads during heavy rain. Why was sediment left at this place? Make a section through the deposit and notice the positions of the coarse and fine layers. Why was the material deposited in this fashion?

(vi) Visit a nearby brook and notice where it is under-cutting its banks. Is there any indication that landslides occur along the banks?

Are there any gullies in cultivated fields that slope towards the stream? Examine the soil in the bed of a gully. Compare it with the surface soil of the field. Find places where the stream deposits sediment, and describe the appearance of the material deposited. Account for the deposition of sediment at certain places. Inquire if the volume of water in the stream is as great as it was forty or fifty years ago. If a change has taken place, try to discover the reasons for it.



(Courtesy of the U.S. Dept. Agr.)

Fig. 178. Bench terraces in the Philippine Islands.

PROBLEM IV: How has ice acted as a sculptor of the earth's surface?

In early geological times, most of Canada was covered with ice-sheets. A large part of its surface has been moulded by ice. Some thousands of square miles of ice-sheet still remain on Baffin and Ellesmere lands in the far north, while many mountain glaciers are to be seen in the mountain areas of Alberta, British Columbia and the Yukon territory.

This glaciation on our continent began in the Rocky Mountains, where small mountain glaciers expanded and filled valleys and sent a few tongues through the passes into the prairies to the northeast. The Keewatin sheet reached the foothills of the Rockies in places, extended south into the Mississippi valley and north to Hudson Bay. The Labrador sheet covered the rest of Canada.

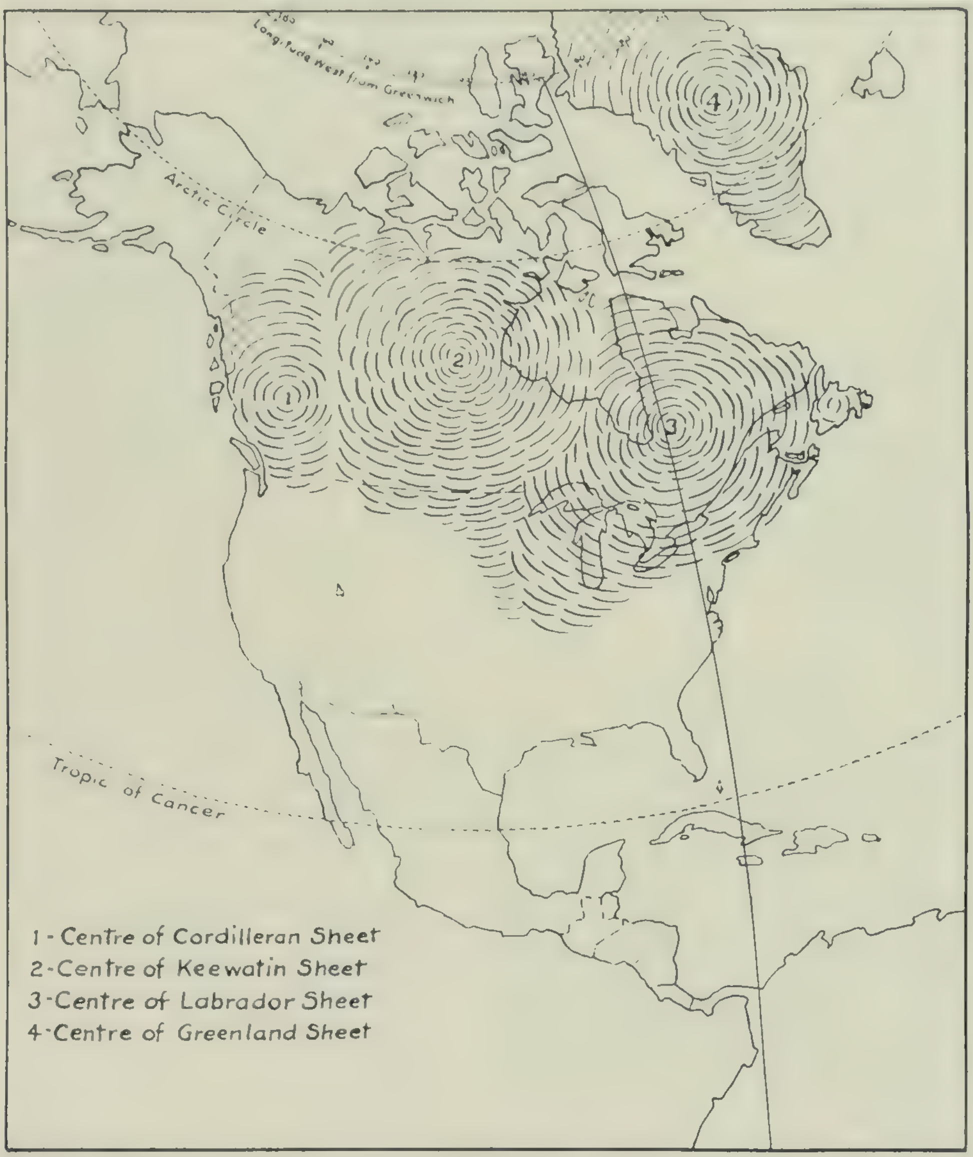
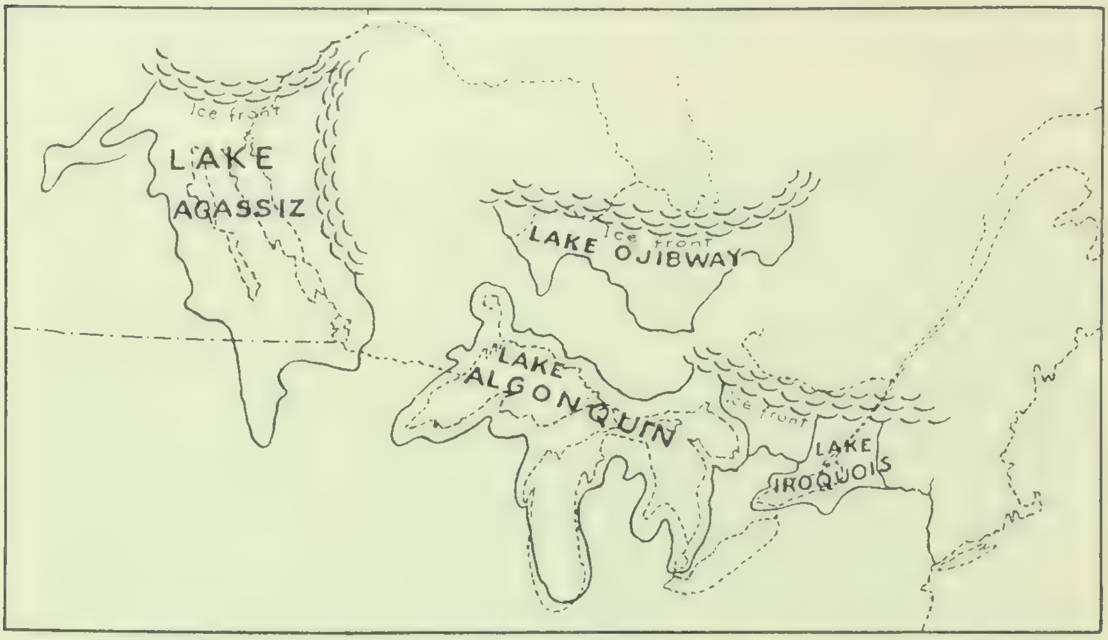

Longitude West from Greenwich
Arctic Circle
Tropic of Cancer
1
2
3
4
1 - Centre of Cordilleran Sheet
2 - Centre of Keewatin Sheet
3 - Centre of Labrador Sheet
4 - Centre of Greenland Sheet

Fig. 179. This map shows that most of Canada and part of the United States were once covered by a great ice sheet.

The Ice Age was interrupted by interglacial periods when the sheets disappeared due to periods of mild climate. As they retreated slowly in the opposite direction from their advance, they left great glacial lakes. Lake Agassiz was an ice-dammed body of water. The fertile soils of the western plains were formed by the silt of this lake. This lake drained through the Nelson river leaving Lake Winnipeg, Lake Manitoba and Lake Winnipegosis.



(From "Elementary Geology" by A. P. Coleman and W. A. Parks. Toronto, J. M. Dent & Sons.)

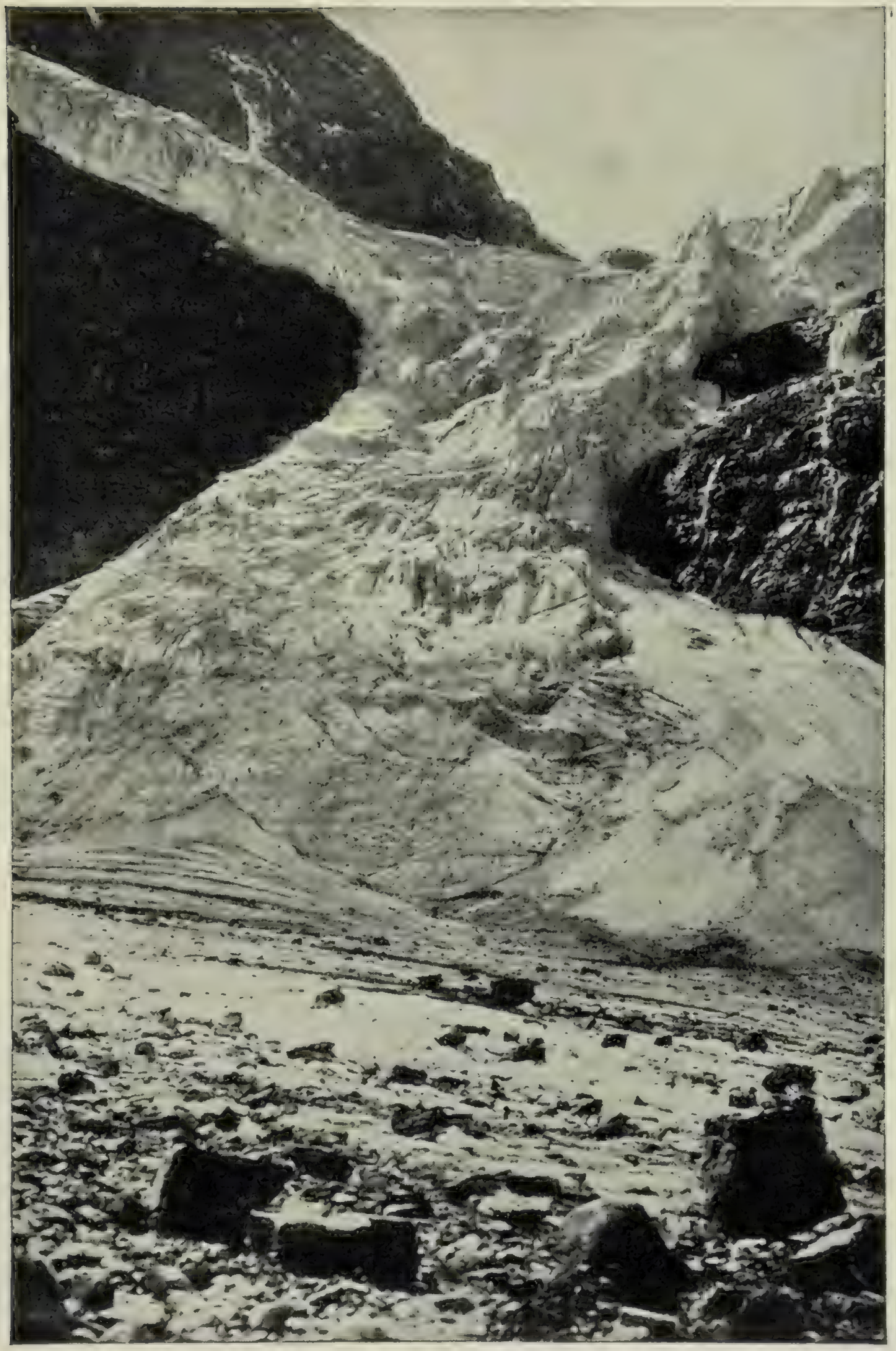
Fig. 180. Sketch map of Post-Glacial Lakes.

Other lakes formed by retreating sheets were Lake Algonquin, Lake Iroquois, and Lake Ojibway. Lake Algonquin was formed by the basins of Superior, Michigan and Huron. Lake Iroquois occupied the basin of Lake Ontario and Lake Ojibway was formed north of the Hudson Bay watershed in Ontario and Quebec.

(Courtesy Geological Survey of Canada.)

Fig. 181. Cypress Hills, Alberta. The tops of these hills were not covered by the ice-sheet that invaded Alberta.

As the glaciers of the far north retreated, lakes were formed because of blocked drainage systems. Gradually, these lakes filled up because of vegetable growth and deposits carried by

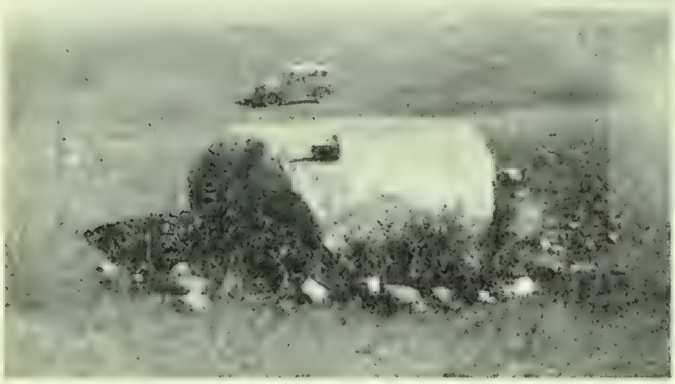


(*Courtesy Geological Survey of Canada.*)

Fig. 182. Water in the solid form. (Ghost Glacier on Edith Cavell Mountain.)

water drainage from higher lands, to become, first, swamps and later, tundra. Thus, we find chains of lakes in the path of receding glaciers.

Ice-sheets pushed onward by pressure from behind moving southward, picked up, sheered off or froze on sand, gravel and rocks and carried them great distances. In some places, the rocks were scoured bare; in others, ridges were left near the margins of the ice-sheets. U-shaped valleys are found in mountains and fiords received their final shaping by valley glaciers.



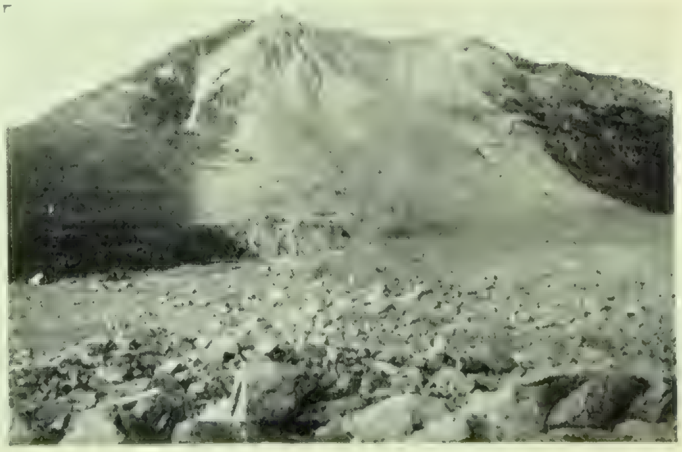
(*Courtesy Geological Survey of Canada.*)

Fig. 183. Buffalo rubbing stone, Driftwood Bend, Old Man River, Alberta.

Blocks of red granite are found on the western prairies at least 500 miles from the nearest source and some 3,000 feet above their starting point, indicating that these blocks as well as the whole ice-sheet have been pushed uphill.

PROBLEM V: **What are crustal movements?**

These changes in the earth's outer crust may appear as earthquakes and landslides causing great and sudden damage. Also, they may come very slowly and result in a sinking or rising of parts of the coast line. When the land sinks, valleys are flooded by the sea and form long narrow inlets. A



(*Courtesy Geological Survey of Canada.*)

Fig. 184. Landslide, Turtle Mountain, Frank, Alberta.

rising coast produces a regular shore-line with great sandy beaches and an absence of capes and islands.

PROBLEM VI: What are volcanoes?

A volcano is an opening in the earth's surface. Lava, which is melted by friction and pressure, has a surface temperature estimated to be between 2,200 and 3,000 degrees F. This lava melts its way to the surface where a weak place permits it to flow out. There it forms a cone which increases in size with each eruption until a mountain is gradually built. Always, there is a chimney through which lava can escape from an active volcano. The active volcanoes nearest to Canadian territory are found in Alaska.

PROBLEM VII: What are earthquakes

Earthquakes are sometimes associated with volcanoes. (Such an earthquake was produced by the eruption of Tokachi in 1925.) Some earth movements take place quietly, but others cause strains which are suddenly relieved. Where a great area of land is elevated in such an earth movement, there must be some support beneath. The earth's crust is far too weak to stand like an arch with nothing beneath it. There may be a gradual shifting of matter beneath the earth's solid crust, or the rocks may break and rearrange themselves. The resulting shock is a wave in the solid rock that may shake entire continents. The shock is measured by an instrument called a seismograph. No destructive earthquake of which we have a written record has taken place in Canada. Earthquakes in Alaska in 1899 raised parts of the coast 47 feet above its former level. Not only are there elevations of the land, but there are subsidences also. The breaking of cables in the Mediterranean Sea was attributed to a sinking of the bottom. In the Mississippi Valley, a drop in the land level caused by earthquakes of 1811-1813, brought into existence lakes in which trees growing prior to the change may still be seen.

PROBLEM VIII: Where are the oceans of the world located, and of what value are they to man?

Ocean water is centred around the south polar region, with triangular tongues projecting northward between the continents. These continental masses divide them into four divisions known as the Pacific, Atlantic, Indian and Arctic Oceans.

This separation of the continents has interfered with the spread of man. To-day, science spans the barriers of water by boats of many kinds and flying ships.

Besides being the route and highway of navigation, the oceans are a source of food for man. Fishes and other valuable animals are caught and used for commercial purposes. Salt, potash, phosphorus, and iodine come directly or indirectly from the ocean. Salt, known to us when purified as table salt, is used in our kitchens and on our tables for seasoning our food; potash and phosphorus are important plant foods; iodine is valuable as a disinfectant for cuts, and is used widely by stock growers in the treatment of goitre among their animals.

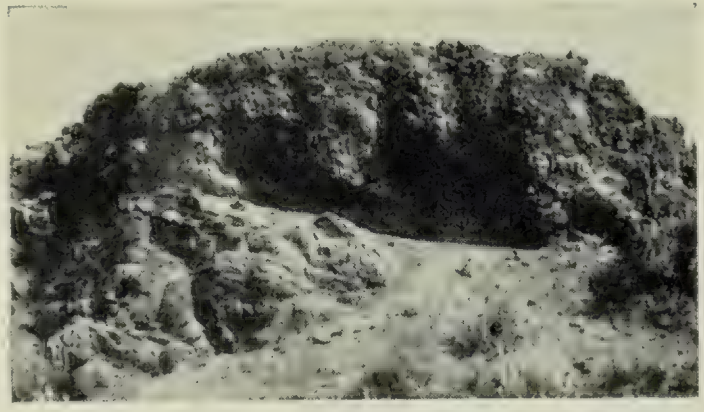
Most of our rain and snow originate in ocean water. Without this moisture, plant life could not grow on the earth. Oceans regulate temperature in that they absorb heat more slowly and cool more slowly than land. Thus, they moderate the winds which blow around them.

D. MINOR STUDY: The earth's crust is composed of many kinds of rocks.

The crust of the earth is composed of rock, a term which includes not only the hard substances familiar to everyone, but also the relatively shallow covering of soil.

PROBLEM I: What are igneous rocks?

It is common knowledge that the temperature rises, as we descend into a mine. Differing rates of increase have been found but the average would appear to be about one Fahrenheit degree for 50 to 80 feet of descent. If this rate were maintained, a temperature of approximately 4000°F would be reached at a depth of 50 miles, which at the earth's surface would convert rocks to the molten state. How then can it be asserted that the earth's core is solid? The existence of enormous pressure in the interior of the earth is considered to be the reason why the material is solid rather than molten. Where the crust is relatively weak, or when the pressure at certain places is greatly increased, rock in an intensely hot state may be forced upward. As it rises, the pressure becomes less and the rock melts. It may be added that the upthrust of the rocks is an additional source of great heat through friction, just as a coin may be heated by rubbing it to and fro on a board. If the molten rock escapes through a vent in the crust, we say that a volcano is active. The presence of very hot water which is converted explosively into steam when the pressure is reduced adds to the violence of the volcano. Frequently, the molten rock does not escape through the surface but forces itself in sheets or masses between other rocks in the crust. That which is exposed to the air is called lava. It cools much more quickly than the imprisoned molten rock and is characterized by a finer grain when solidified. Sometimes, the granulation is so fine that a natural glass, *obsidian* is formed. The porous stone called *pumice* is another example of lava.



(Courtesy Geological Survey of Canada.)

Fig. 185. Intrusive plug on the north bank of Milk River at the mouth of Pendant d'Oreille Coulee, Alberta.

Rocks produced in this manner are termed igneous (Lat. *ignis,* fire). They are common in areas of active volcanic action, for example, Alaska, Iceland, the Hawaiian Islands, Italy and Japan, but even in regions such as the Cordillera and the Canadian Shield where there has been no volcano within historical times, igneous rocks are abundant. Their presence in such places indicates the flow of molten rock in remote ages.

Granite, used extensively for monuments and in building, is a common igneous rock which cooled slowly below the surface.

The following clipping is from *Current Science*:

> "Granite comes to its toughness by a path of fire. Much of the earth's crust has once been melted by the earth's internal heat. Silica (Latin—"flint stuff")—which when pure we call quartz, and when fine we call sand—is a stuff that when molten soaks up the rock-forming minerals, as water takes up salt and sugar. These minerals lose themselves in the fervent heat of the syrupy mass that is often pushed out over the crust of the earth.
>
> After the stir of heat comes the quiet of cooling. In granite, three minerals separate as crystals. One is pure quartz or silica; it makes the glassy material. Another is feldspar (old German, "field rock"), the coloured portion. The third is mica (Latin—"crumb"), the shiny specks in granite.
>
> As the minerals grow as crystals in the cooling mass, they press in and around each other so tightly that neither the winds of the plains nor the waves of the coasts can wear them away except with exceeding slowness."

Whenever you find an interesting newspaper item such as this one, clip it and paste it in your scrapbook. Many similar articles are found in this attractive little paper published by the American Press Inc., 400 S. Front St., Columbus, Ohio, and sold for 75c. a year.

To observe what happens when some molten substances cool.

Place some sulphur in a crucible or evaporating dish. Heat cautiously. As the sulphur melts, add more until the dish is nearly full. When all is melted, remove the burner. As soon as a thin crust has formed, pierce it in two places as widely separated as the dish permits. Pour out the still molten sulphur through one of the holes (Recall the pouring of condensed milk from a can.) Remove the crust and examine the under side. Describe the crystals formed. Do all molten substances form crystals when they solidify? Recall the cooling of molten paraffin wax.

Give some examples of crystalline substances. Examine the zinc coat on a galvanized iron furnace pipe. Suggest a possible property of rocks which have solidified from the molten state.

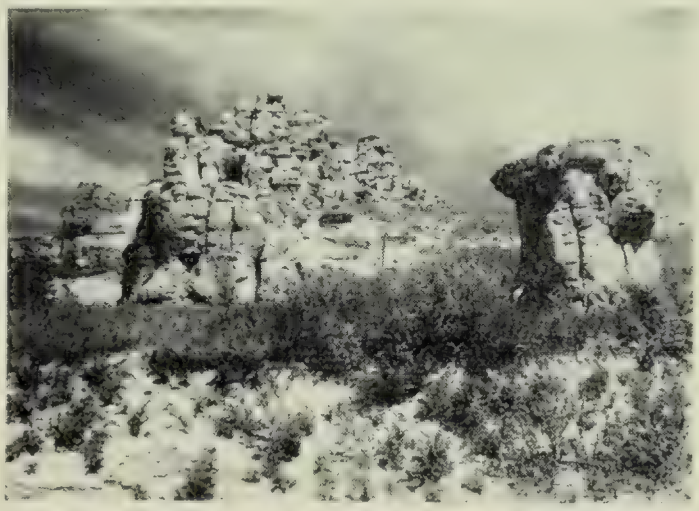
Suggest another method of producing crystals. Try it.

Study of igneous rocks.

With the aid of a magnifying glass, examine specimens of rock that have been formed by the solidification of molten substances, e.g. granite, syenite, trap. Are the rocks uniform in appearance or do they appear to be composed of several constituents (minerals)? Do you notice any crystals? Describe the colours.

PROBLEM II: What are sedimentary rocks?

(i) Draw to scale several hundred yards of the course of a little stream. Show on your drawings the approximate speed at four or five points. Describe the rocks, stone, gravel or sand found along the bed. Look for undercutting along the banks. Examine a sandy deposit. Remove carefully a thin layer. Do you notice any difference in coarseness between the particles beneath and those on top? Remove a number of layers. Give an explanation for the various phenomena you observe.



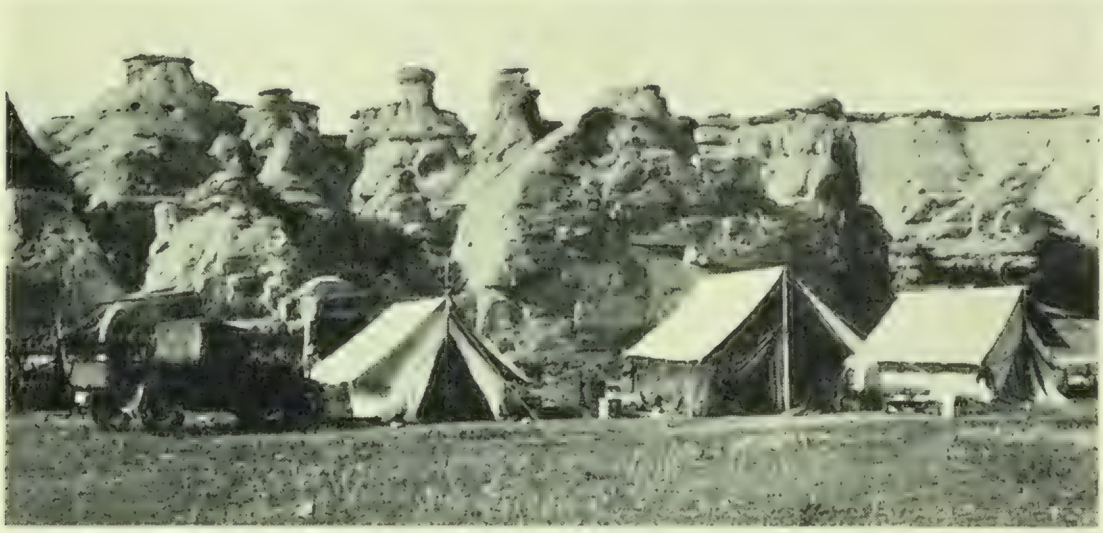
(Courtesy Geological Survey of Canada.)

Fig. 186. Blood Reserve sandstone, Milk River ridge, Alberta.

(ii) Visit a limestone quarry and a sand pit. Are there any features in common? Make drawings of a vertical section.

(iii) Examine specimens of sedimentary rock, e.g. limestone, shale, sandstone. Notice the layers. Using a piece of glass tubing, place a drop of hydrochloric acid on each. Test samples of igneous rock also in this manner. If lime is present, effervescence will take place. If enough gas can be caught and passed through limewater, the liquid will turn milky in colour indicating that the gas is carbon dioxide.

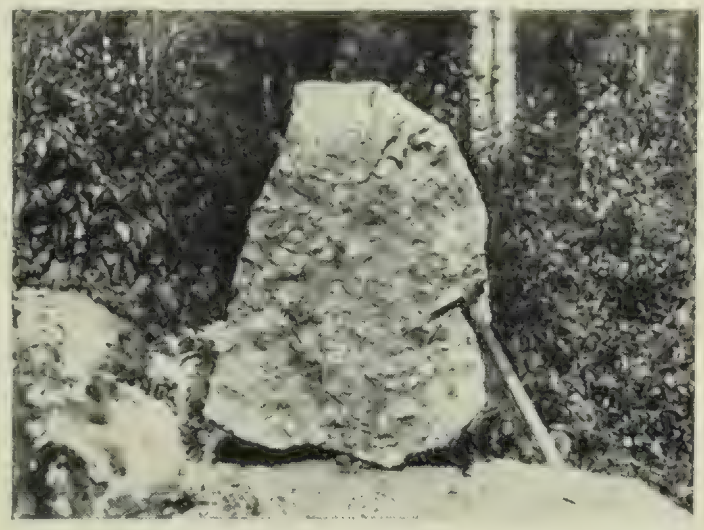
The muddy runlet on the roadside is a familiar sight. If we observe where the speed of the water is lessened by obstructions, by the spreading out of the stream, or by arrival at comparatively level ground, we shall notice when the flow has ceased that sand has been deposited. In a similar manner, rivers carry material from high ground and lay it down when the force of the current is checked by the above agencies, or by entrance into a lake or sea. If we scrape the surface of one of these sand deposits, we may find the finest particles on top and the coarser layers below. Where there has been little change in the force of the water for a considerable time, this arrangement into layers of different coarseness may not be found. When the stream is flowing rapidly, only heavier particles of its load sink to the bottom. As the speed becomes reduced, fine particles settle down. Again, any change in the nature of the material carried by the water would cause a corresponding alteration in the pattern of layers. Grains of sand, produced by the endless breaking of waves on rocks along the seacoast, are carried by currents and deposited on bars or beaches close at hand.



(Courtesy Geological Survey of Canada.)

Fig. 187. Camp at Leslie Ranch, Lower Milk River sandstone, Alberta.

Invariably, there is more or less mineral matter in water such as lime, silica, or iron. This is derived from rocks. These substances serve as cements to bind together the water-borne particles of clay or sand. Pressure from the accumulating material above, together with the binding mineral, cause the formation of the rocks sandstone and shale. The former is derived from sand; the latter from clay.

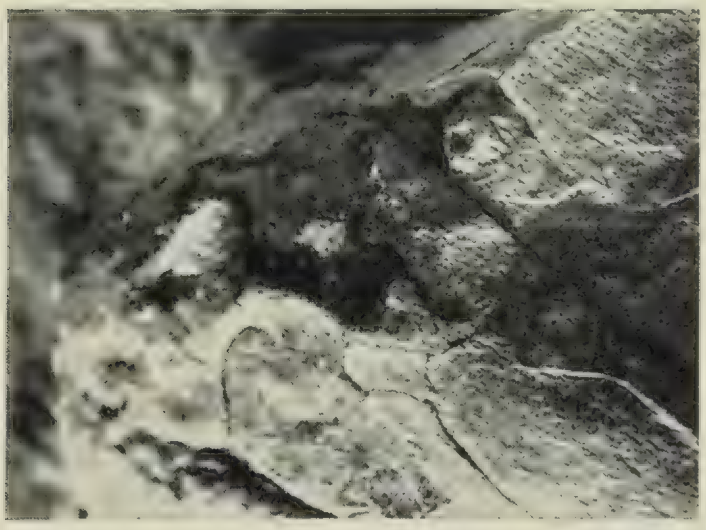


(*Courtesy Geological Survey of Canada.*)

Fig. 188. Limestone, Birch Lake formation, Alberta.

Each of countless billions of tiny salt-water organisms makes on its death a very small contribution to our rocks. The hard parts, largely composed of lime, sink to the bottom. As the mass accumulates, the effect of pressure and mineral cement causes formation of *limestone* rock. To a much lesser extent, fresh-water organisms have produced similar deposits.

Rocks originally laid down in horizontal layers are said to be sedimentary. Although the examples mentioned, namely sandstone, shale, and limestone, were formed under water, sedimentary rocks may be produced also by the transporting action of winds.



(*Courtesy Geological Survey of Canada.*)

Fig. 189. Surface of gneiss boulder worn by wind-blown sand, near Red Deer River, north of Bindloss, Alberta.

Shale is used in the manufacture of bricks. Sandstone is employed extensively in building, as is also limestone. To the durability of the latter the Pyramids of Egypt bear witness. Although considered rather soft for the purpose, limestone is used in road construction. Farmers find it valuable as a "sweetener" of acid soils. As a flux for iron ore it is important in smelting.

NOTE: Minerals from which a metal can be extracted are called ores.

PROBLEM III: What are metamorphic (or altered) rocks?

Sedimentary and igneous rocks may undergo alteration through the effect of heat and pressure. Movements of the earth's crust cause the production of heat which, although insufficient to melt the rocks, is able, with the assistance of great pressure, to make marked changes in their structure. Rocks thus altered are described as metamorphic. (Gk. *meta*, change; *morphe,* form). Limestone is converted into the metamorphic rock *marble,* shale into *slate*, sandstone into *quartzite,* and granite into *gneiss.*

It is clear that these changes must take place below the earth's surface, so that wherever masses of metamorphic rock are found, we may conclude that the covering rocks have been worn down. This is the case in the Canadian Shield whence boulders of gneiss have been carried by glaciers to southern Ontario.

Metamorphic rocks are of considerable economic value. Marble, while highly prized for interior decorative work and for statuary, is too rapidly weathered for satisfactory use out of doors. In this connection we remember how after a comparatively few years the wording on marble tombstones becomes difficult to read. Slate is a common roofing material in Europe and makes an excellent classroom "blackboard."

Study of metamorphic rocks.

With the aid of a magnifying glass, examine specimens of metamorphic rocks, e.g. marble, slate, gneiss. Notice the degree of difficulty with which each is scratched with a knife. Compare each in hardness and appearance with the igneous or sedimentary rock from which it was derived. Try the effect of hydrochloric acid. Is there an effervescence? If so, what would it indicate to you as to the origin of the rock?

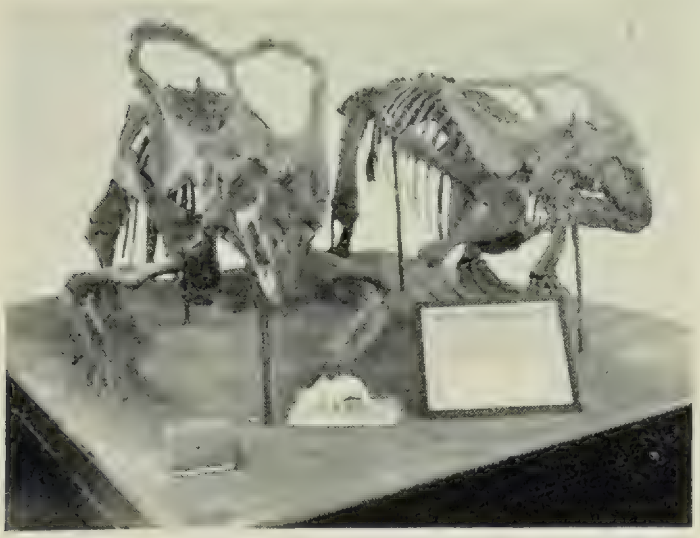
Exercises:

1. Make a collection of the rocks of the neighbourhood.
2. Observe types of rocks commonly used for different kinds of buildings. Give reasons for the selection of each type.
3. On a map of Canada, locate Lake Agassiz and Lake Iroquois.
4. Study a map of Alberta and note in the far north, the chains of small lakes and marsh lands as indications of lack of a drainage system. Compare the raising of the altitude of the Great Lakes and the consequent lowering of the water level.
5. Try the effect of hydrochloric acid on marble.

E. MINOR STUDY: Fossils help to tell the age of rocks.

PROBLEM I: What is the story written on the rocks?

There is a history which can hardly fail to excite the imagination and arouse our wonder. It is a story of the grandeur of nature and the play of vast forces, and is written on the rocks in a language often presenting serious difficulty to the reader. Most of the chapters are missing wholly or in part. Many of the pages are in tatters.

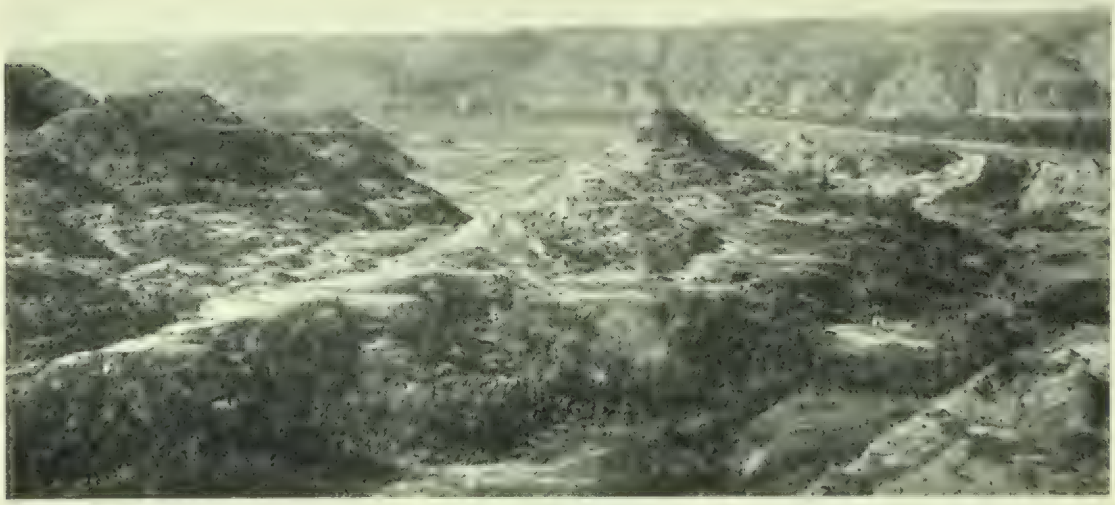


(Courtesy National Museum of Canada.)

Fig. 190. Horned Dinosaurs whose skeletons were found in Alberta.

One may ask about the language in which the story is written. Let us imagine a plant or animal dying in a place where its remains are covered with mud or sand. The hard portions, washed with water seeping through the sediment, have their particles gradually exchanged for others of some dissolved mineral such as lime. Thus a fossil is formed in which the details of the original shell or stem are reproduced with the exactness of a plaster cast. It was once believed that these fossils were the remains of animals or plants submerged during the Flood. They are often found in sedimentary rocks. Also classed as fossils are the footprints of prehistoric animals, the preserved ripple marks on the shore of an ancient sea, and pitted shale, evidence of rain on the mud of a million years ago.

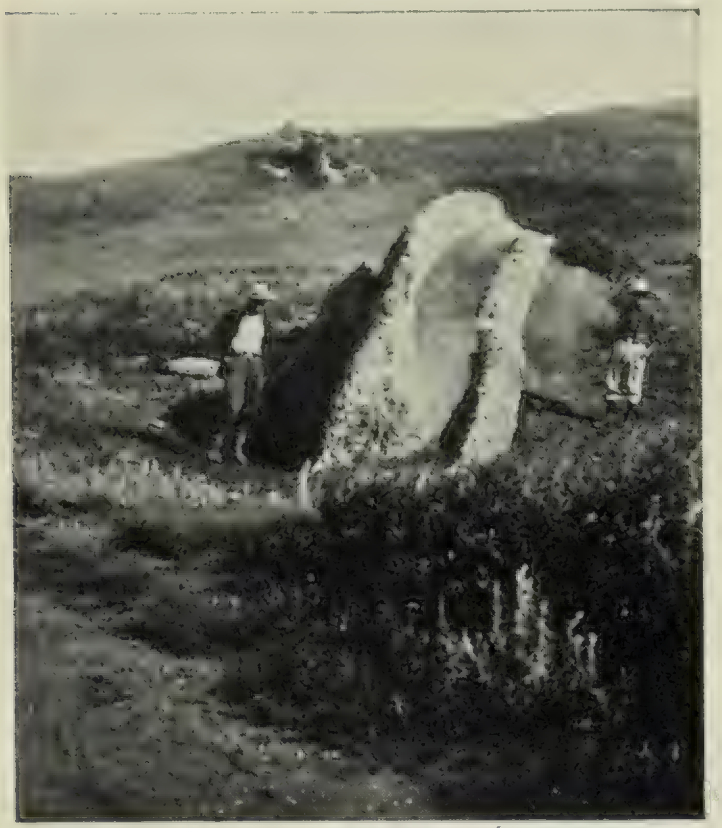
Fossils are valuable aids in understanding the story of the earth. Not only do they give information concerning long extinct plants and animals, but they throw light on climatic changes. For instance, fossils from the Don River valley near Toronto indicate the existence there at one time of a climate very much milder than the present one. Remains of crocodiles and palm leaves have been found in England in the vicinity of London. Unless the sedimentary rocks have been disturbed by a movement of the crust, the underlying layers or *strata* (singular, stratum) are older than those above. Thus, much is learned about the order in which different forms of life appeared on earth. Successive layers of sedimentary rocks from the first deposited to the most recent contain fossils representative of the plant and animal life then living. So, by comparison of the fossils obtained from rocks in different localities, those who have devoted themselves to this



(Courtesy Geological Survey of Canada.)

Fig. 191. Badlands near Rumsey, Alberta.

branch of science can tell which layers are of about the same age. No fossils of fish have been found in rocks earlier than those of a certain period. Fossils of mammals do not appear unless in rocks of quite recent formation.



(Courtesy Geological Survey of Canada.)

Fig. 192. Oyster bed, St. Mary River sandstone north-west of Kimball, Alberta.

There are other clues for those curious to read the history of mother earth. Often the shells of sea-animals are found far inland, even on high mountains. How could you account for this? There are the marks made on rocks by boulders carried by glaciers. In Canada and the Northern States, huge boulders are found hundreds of miles south of the place from which they came. Boulders of granite originating in Scandinavia have been discovered in England. Near Drumheller, Alberta, there is a "forest" of petrified wood. Many sea fossils are found on Moose Mountain, west of Priddis, Alberta. From our study of this material we can reconstruct, in part, climatic conditions in this area when these trees grew on the earth.

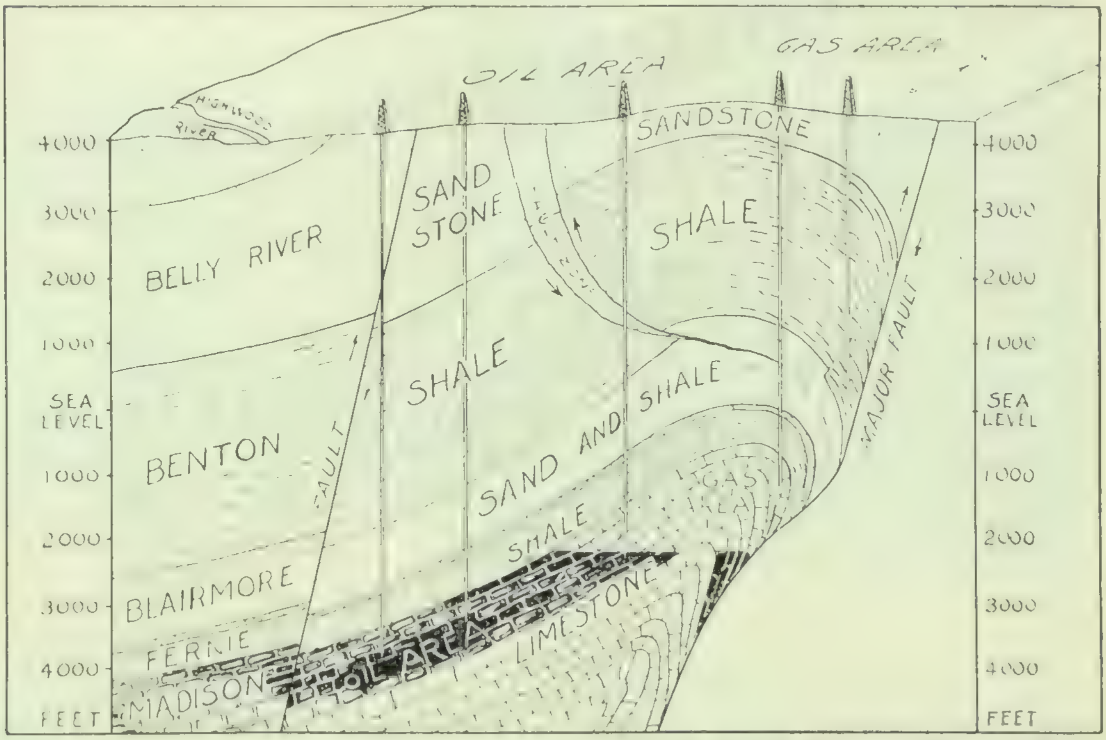
ENRICHMENT SECTION, NUMBER 10.

The log of a well in Turner Valley.

Each stratum bears the name it does because of a characteristic peculiar to the region, or because it resembles a particular formation first discovered elsewhere.

The first geologist to discover a limestone formation in the Madison, Wisconsin, area, called it the Madison Limestone. When a similar formation was found in Turner Valley, it was given the same name.

For the first five or six hundred feet the drill penetrates the Belly River Sands, so named by G. M. Dawson following a geological study of the area southwest of Lethbridge, where he first found them. (Hills in the Turner Valley area are composed chiefly of Belly River sands.) The drill next enters the upper Colorado or Benton shales, getting their name from Fort Benton in Montana. Dominion geologists know them as Alberta shales. These extend for about fifteen hundred feet and overlie the Cardium sandstone which is about seventy-five feet thick. The Cardium (Gk. *kardia*, heart) sandstone was so named by D. D. Cairns because he found in this formation heart-shaped fossils. Next, the drill goes through six hundred to eight hundred feet of lower Colorado shales, and then the Blairmore formation for approximately twelve hundred and



(Courtesy of Dr. Conway, Victoria, B.C.)

Fig. 193. Earth formation at Turney Valley, Alberta. This is Canada's largest oil field.

fifty feet. A one hundred and fifty foot thickness of Kootenay formation is found underlying the Blairmore before the Fernie formation is struck directly above the Madison limestone. When the limestone is reached, drilling is continued for about four hundred and fifty feet before oil can be obtained.

A Dominion government geologist, W. W. Leach, named the Blairmore formation for the town of Blairmore, in which he first studied it. The Kootenay formation was named by Dr. A. R. C. Selwyn, director of a Dominion survey in 1869 in the Kootenay area. The Fernie shale was called after the town of Fernie.

Exercises:

1. Make a cross-section drawing of a well in Turner Valley labelling each formation.
2. What is the approximate depth of a well in Turner Valley?
3. Mount in your scrapbook pictures of Turner Valley.
4. In what sense have we used the term 'log'?

ENRICHMENT SECTION, NUMBER 11.

A theory to account for the formation of coal and oil.

NOTE: Remember that this is a *theory.*

Coal is a mineral formed from vegetation that grew in fresh water marshes on this earth millions of years ago. When this vegetation died, it fell into the water and formed layers of decaying matter. Decomposition bacteria that live in fresh water changed this mass of trees, branches, leaves, ferns, etc., into a black mud, often pure carbon, which settled to the bottom. Gases such as oxygen, nitrogen, and hydrogen were given off in the process of decaying. Upheavals of the earth's crust caused rivers to bring this mud to river mouths and the open sea. The salt water killed the bacteria, stopping the carbonization of the mud at whatever stage it was in. Thus we have lignite, sub-bituminous, bituminous, and anthracite coal.

Oil-fields are always found near present or ancient shore lines. During the decomposition of plant and animal life in the marsh bottoms, oil was set free and held in the mud. This oil was also drained by rivers, and, being lighter, was carried beyond the black mud that formed the coal. The oil globules came together and formed pools in the sand. This oil flowed through porous sandstone or limestone, or through faults or seams, to be finally trapped in some inverted cup or anticline.

Factors such as time and heat caused the oil to give off natural gas, or converted whole pools into gas. The gas either remained in solution in the oil, just as carbon dioxide is held in soda-water, or it formed in the top of domed anticlines where it acts as the force that pushes the oil up to and out of the mouth of the oil well.

Exercises:

1. Visit a coal mine and make a report of what you observe.
2. Why is the coal formed in layers or seams?
3. Ask the miners if they have ever found (a) what appeared to be a tree trunk among the coal, (b) fossil remains of fish.
4. Locate on a map of Alberta the various areas in which coal is found.
5. How important is Alberta as a producer of coal?

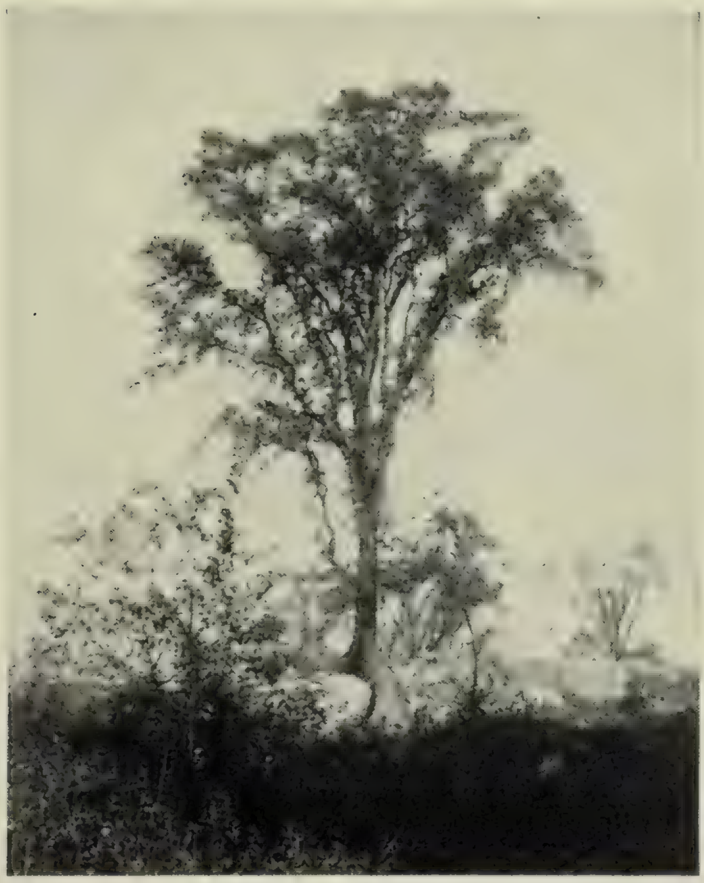
F. MINOR STUDY: Much of the upper part of the earth's crust is soil.

PROBLEM I: How is soil formed?

In autumn the annual carpet of brown is spread on the forest floor. Beneath this cover, we find damp leaves of the previous year in various stages of decay, and under them the rich black soil called *humus*. This soil, formed largely from the partially decayed remains of plants, is common in swamps as 'muck' or 'peat'.

The greater part of most soils is not humus but tiny particles derived from the breaking down of rocks. We have already learned how this very slow process is affected by water, air, wind, change of temperature, and plant roots. In addition to these reducing agents, there are others which play a very useful part in soil production.

Humus is added to the soil by the use of farm manure, the ploughing in of green crops, and the decay of roots or other parts of plants. If it were not for armies of plants, so small that they are visible only under the microscope, no plant or animal, however long dead, could decay. These small organisms, called bacteria (singular bacterium) use animal or vegetable remains for food. The effect is to bring about gradual changes in the original substances. It is not until these changes are made that the material becomes suitable for the food of those larger plants which we see with the naked eye. Later, we shall learn how certain bacteria which live in the roots of clover and related plants increase the productiveness of the soil. It may be mentioned that some kinds of bacteria in their life activities attack even the mineral constituents of rocks thus assisting in the process of reduction already described. For instance a slimy red mud, is evidence of bacterial action on a mineral containing iron.



(*Courtesy Geological Survey of Canada.*)

Fig. 194. Tree splitting a rock.

Darwin drew attention to the silent but effective work of earthworms. These animals eat their way through the soil. From the material consumed, the nourishing portions, such as humus, are selected by the digestive organs. The remainder, consisting of tiny particles derived from the original rock, is excreted. In passing through the worm, the grains of sand are rubbed together by muscular action so that they emerge reduced in size. Darwin estimated the worm population of an acre that he was observing, at 50,000. In a year, these worms would pass from 10 to 18 tons of soil through their bodies producing castings sufficient to raise the level of the acre of land by one-tenth of an inch. Within thirty years, a stony field was completely covered with a concealing layer of turf.

In forming galleries or burrows, the earthworm makes a further contribution. These permit the entrance and circulation of air and water which as we have seen are also active agents in breaking down rocks and rock fragments. Also, plants thrive best in a well-aired soil. A similar service is performed by burrowing mammals such as the mole, and the gopher.

Darwin's interesting observations have emphasized the importance of earthworms in soil building, but it is believed by some authorities that soil insects make a contribution of equal value. Counts made of the beetles, ants, bees, cutworms, and other insect inhabitants of soil reveal their presence to the extent of millions per acre. By their burrowing activities and the additions made by their excretions and dead bodies, the fertility of the soil is increased. There is reason to believe that the excretions of insects exceed in amount that of the larger animals.

PROBLEM II: Can water be used to separate soil constituents?

Place powdered garden soil in a tall glass vessel to a height about one-fifth that of the jar. Add water until the container is nearly full. Shake the mixture very thoroughly and then allow it to settle. Examine carefully for the first two or three minutes and again in half an hour. Allow the jar to remain undisturbed for several days. When did the cloudiness finally disappear? Did any material remain at the surface? Give an explanation of what you observed.

Examination of a soil.

(i) Examine under a hand lens a sample of air-dried garden soil. Notice the colour, shape and size of the particles. Do you see any material which may be produced by plant decay?

(ii) Place a very small amount of the soil on a microscope slide. Moisten it with water and examine under the low power lens. Do you observe a black substance adhering to any of the particles?

PROBLEM III: What are the different kinds of soils?

The settling down of soil, previously shaken vigorously with water, is interesting to watch. Fairly distinct layers are soon formed, those of coarse material at the bottom, those of fine at the top. Some days may pass before the cloudiness finally disappears. This sorting action of water was noticed before in connection with the eroding and transporting action of streams. First to fall down are the particles of gravel; then, fairly rapidly in succession, come coarse, medium, fine, and very fine sand. Tiny particles of silt settle on the finest sand and, last of all, the clay comes down. Fragments of partly decayed vegetation may be seen floating. One would not expect in this manner to get a perfect separation of the soil into layers of like size. A certain amount of mixing takes place.

A simple calculation shows us that 5,000 of the largest particles of clay laid side by side would hardly measure an inch. The smallest particles are barely seen under a powerful microscope. A product of the weathering of the mineral feldspar in granite, clay has a number of uses besides its rôle as soil. Its plasticity when wet permits it to be moulded. Then, if strongly heated, it hardens while retaining its shape. These properties make possible the manufacture of brick, pottery, and tile.

Silt is composed of particles with a similar origin. Although very small, they are much larger than those of clay. On that account, wet silt lacks the stickiness found in finer substances.

When granite is broken down, the mineral quartz is gradually reduced to fine sand. Also, a relatively small amount of sand remains when limestone is dissolved by water containing carbon dioxide. Previously, we learned that sandstone is a sedimentary rock formed by the binding of sand particles together, an example of one rock constructed from the wreckage of another.

The approximate measurements of these soil constituents is given below. It is not to be assumed that the particles are uniformly spherical.

Constituent	Diameter of particle in fractions of an inch.		
Clay	$\frac{1}{250,000}$	to	$\frac{1}{5,000}$
Silt	$\frac{1}{5,000}$	to	$\frac{1}{500}$
Very fine sand	$\frac{1}{500}$	to	$\frac{1}{250}$
Fine sand	$\frac{1}{250}$	to	$\frac{1}{100}$
Medium sand	$\frac{1}{100}$	to	$\frac{1}{50}$
Coarse sand	$\frac{1}{50}$	to	$\frac{1}{25}$
Fine gravel	$\frac{1}{25}$	to	$\frac{1}{10}$

Soils are frequently classified according to the proportions in which these ingredients are present. In the following table, the classes are determined by the percentage of silt and clay combined.

Soil	Percentage of silt and clay.
Heavy clay	90-100
Clay	75-90
Clay loam	60-75
Loam	40-60
Sandy loam	25-40
Light sandy soil	10-25
Sand	0-10

PROBLEM IV: What are the characteristics of different types of soil?

Mix small amounts of sandy soil, loam, clay, and muck with enough water to make them thoroughly saturated. Place the containers on a radiator or near a stove until the soil becomes dry. From your observations decide which type is most easily worked after rain. Which is most likely to delay farm operations in spring?

A sandy soil does not become sticky when wet, nor is it hard and compact after drying. These properties make for easy cultivation. It is quite porous and thus allows rapid circulation of air and water. It is a warm soil, that is to say it is easily heated. Unfortunately, sandy soils are often lacking in plant food, due in part to the readiness with which water passes through them. Again, since sandy soils dry rapidly, crops growing on them frequently suffer severely in periods of drought.

The very properties of clay which make it so suitable for the manufacture of brick and pottery cause great trouble to the farmer. If he cultivates his clay land when wet, the soil on drying forms hard compact masses. Hence, in a wet spring, farm operations on clay soils are delayed. This soil does not permit water and air to circulate freely. It is often difficult to drain. Clay retains water well, but the presence of this moisture causes the soil to heat slowly. In this connection, we recall the moderating effect on temperature of large bodies of water. Curiously enough, the fact that clay retains water well does not always make it a desirable soil in dry weather. A crop may suffer from drought in a clayey soil more than in a sandy soil actually much drier on account of the greater ease with which the latter type gives up its moisture. Soil particles in clay hold on to their water films more firmly than do the particles of sand. Also, the hardness of the clay in dry weather often hinders plant roots from penetrating to lower levels in search of water. In wet weather, this soil may become so full of water that air, which is so necessary for vigorous plant growth, is excluded. In general, soils of a very clayey nature are not considered desirable for cultivation.

It is customary to describe soils containing a considerable proportion of sand as 'light' and those in which silt and clay predominate as 'heavy'. This refers to the ease with which cultivation is carried on. In reality, a cubic foot of 'light' sandy soil weighs from 25 to 40 pounds more than the same volume of 'heavy clay'.

Loam, which has a middle position between sand and the silt or clay soils, has no tendency to harden. It is easily worked and sufficiently open to permit a good circulation of air and water.

The kinds of farming that will be followed in the Province of Alberta are already determined more or less by types of soil and country. Ranching, particularly the raising of horses and cattle, is suited to the foothills districts. The southern prairie areas are especially adapted to grain with a growing tendency toward mixed farming. The central and northern districts are essentially mixed farming sections, where, in addition to substantial production of wheat and coarse grains, cattle and hogs are raised in large numbers. Over a million hogs are now marketed from Alberta annually, this Province standing very close to Ontario for the highest prizes in hog raising. Dairying and poultry farming also are rapidly becoming important industries as markets outside the Province are developed.

PROBLEM V: What percentage of humus is found in soil?

Recalling the origin of humus, suggest a means of removing this substance from a sample of soil. What procedure would you adopt in order to find how much humus there was present in a given weight of soil? Your sample would undoubtedly contain some water. How could this difficulty be overcome?

Pulverize a small amount of soil from which the larger pieces of gravel have been removed. Dry it for several hours at a temperature between 100°C and 110°C (212°F. to 230°F.). Heat a known weight in a crucible until a dull red glow has been maintained for about five minutes. Allow the crucible to cool. Then weigh it. Heat and weigh again. If there is no change in weight, all the material of vegetable origin has been burned off. If not, continue these operations until no further loss occurs Find the loss in weight and express this loss as a percentage of the original weight of soil.

Find the percentage of humus in different kinds of soil. Compare samples of surface and sub-soil in this respect.

(NOTE: Limestone is converted into quicklime by strong heat. At the same time, a gas, carbon dioxide, escapes. Thus, the remaining quicklime is lighter than the original limestone. How would the presence of limestone in your sample of soil affect the percentage of humus calculated?)

Humus is present in all cultivated soils, generally to an extent of about one to four per cent. In peat the percentage is at least 65, in muck, between 25 and 65. These are special cases. Undoubtedly, this constituent is one of utmost value. It is a storehouse of valuable plant food made available gradually for plant food by the action of bacteria. We find black clothes uncomfortable in summer because they absorb heat. The addition of humus tends to darken a soil and thus make it more easily warmed. Humus particles are very small.

As one would expect, the upper layer of soil is richer in humus than the under-lying part or sub-soil. When we examine a cutting or excavation, we can easily detect the presence of humus by the darker colour of the upper layer of soil. The following figures obtained by the Dominion Department of Agriculture in four tests show the degree to which organic matter is present in samples of surface soil and sub-soil.

	Soil	Percentage of organic matter.
1.	Surface soil	5.67
	Sub-soil	3.63
2.	Surface soil	4.74
	Sub-soil	2.82
3.	Surface soil	4.73
	Sub-soil	3.49
4.	Surface soil	5.12
	Sub-soil	3.51

Colour is important in estimating the character of a soil. It is due almost entirely to the presence of two substances, organic matter and iron in some form. Besides being an indication of the kind of soil, a dark soil warms up more quickly than a light one.

Exercises:

1. Place a black cloth and a white one on snow. Allow the sun to shine on them and note under which the more melting has taken place.
2. Place equal quantities of air-dried light-coloured and dark-coloured soil in the sun and take the temperatures with a thermometer at intervals. Tabulate the readings and attempt to interpret them.

The following is a soil survey of Alberta. From this information, locate the areas on an outline map of Alberta.

Brown prairie soil.

Found in the south eastern section, from the United States boundary north through Taber, Bassano, Hanna and Provost east to Saskatchewan. A highly productive soil which, unfortunately, is mostly included in the dry area of the Province. For this reason, it yields only a portion of its possible crop.

Dark-brown prairie soil.

A soil zone adjoining the brown prairie soil, the westward boundary following the foothills from the United States line to the west of Calgary; thence, irregularly eastward and north to the Camrose and Vermilion areas. A good loam soil reasonably rich in the elements of plant food.

Black loam soil.

The main zone commences in the Carstairs district. It lies west and north of the dark-brown zone, and extends some distance to the west of the Edmonton-Calgary C.P.R. line, north towards Athabasca and east through the Vegreville and St. Paul areas. A soil exceptionally rich in humus and the most productive of the province. A limited area of this soil occurs also south of Calgary to Granum and includes the Vulcan district, a very prolific wheat growing area in normal years. Patches of the same soil are interspersed through the unsurveyed areas of the west and north.

Gray transition soil.

These occur along the southern foothills, in all of that area between the mountains and the black loam zone, and over most of the sparsely settled districts of the west and north, not including the Grande Prairie and Peace River districts. They vary from a very light to a dark gray colour. They are not so productive as those previously mentioned. As their light colour indicates, they have little decayed vegetable matter. Hence, they are deficient in nitrogen. These soils require more skill in tillage than do the others. Unless nitrogenous material is added, they are not suited to grain growing. Clovers and other legumes do well on them. The roots of these crops provide the soil with a supply of nitrogen.

Black gray soil.

This particular type appears to be confined to the Grande Prairie and Peace River country. It is another very excellent soil, producing high yields of all farm crops.

Possibly, no other territory of equal area in the world has the natural resources of soil possessed by Alberta.

PROBLEM VI: How is water retained by soil?

Everyone is familiar with the fact that soil behaves somewhat like absorbent paper in taking up moisture. Before the discovery of blotting-paper, its place was taken by fine sand.

The following problems are of considerable interest and have an important bearing on agriculture.

(a) In comparison with its own weight, how much water can a given sample of soil absorb?

(b) Is there any difference between the different kinds of soils in regard to the amount of water they can absorb?

(c) What becomes of any surplus water that may be added?

Try to plan experiments which would supply answers to these questions.

* * * *

Tie a piece of muslin across one end of a lamp glass and pour in sufficient dry sand to make the chimney about three-quarters full. Support the glass over an empty beaker. Slowly add water from a vessel which originally contained a measured amount.

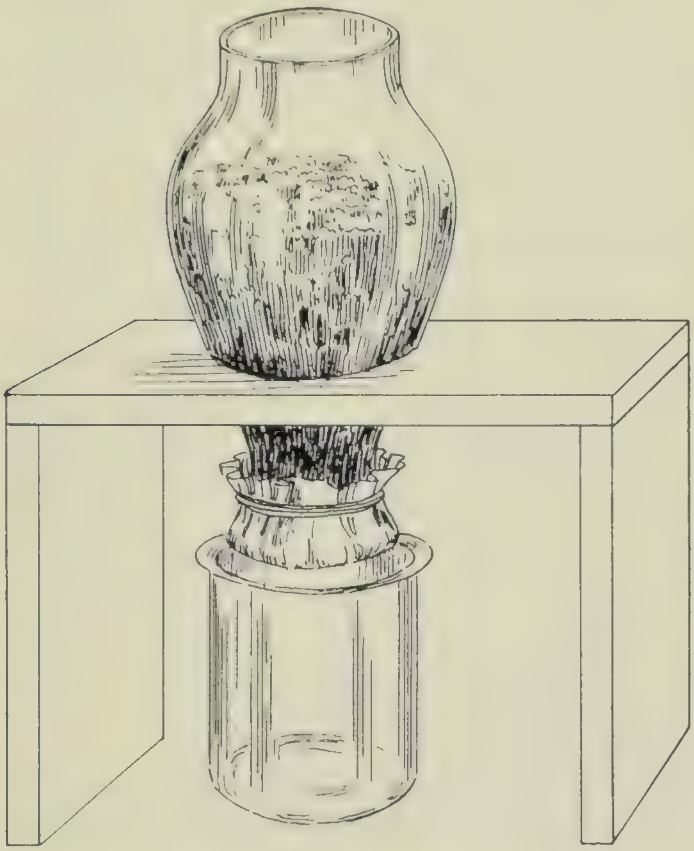


Fig. 195. Water holding capacity of soils.

Note how much water was added before it began to trickle through the cloth. What is the effect of adding additional water?

Compare muck, clay, and loam with sand as to their capacity for water. As far as possible, each soil sample should have the same compactness. Why?

Soluble material in soil.

Filter through filter-paper or blotting-paper some of the water which has percolated through the soil. Pour a little of this clear water on clean watch-glasses. When the water has evaporated, examine the watch glasses. Is there any residue? What is the conclusion?

Where does the water stay in the soil?

Place equal volumes of small marbles, coarse gravel, and sand in lamp-chimneys. Compare the three substances as to their capacity to retain water. Decide where the water is held.

Soil water.

Few people are aware of the vast quantities of water required by growing plants. Not only is moisture needed for the development of their juicy leaves, stems, and roots, and for the ripening of luscious fruits but there are also much greater volumes of water in the vaporous state which pass through the leaves to the air. For instance, 13,000 pounds of water may enter the air from a single acre of grass on a summer day. A single corn plant, well-supplied with water, may give off as much as 5 gallons during the period of its growth. It is estimated that to produce an acre of potatoes yielding 200 bushels, one and a quarter million pounds of water is necessary. Some of this is used in the building up of plant tissue; the rest passes out of the leaves as vapour.

The water retained by the soil is held in the spaces between the particles. These spaces, which are very small, form a continuous network throughout the whole mass of soil. We can easily imagine them by thinking of a barrel of apples or a bottle of marbles. Moisture held in these tiny tubes is called 'capillary' water, (Lat. *capillus,* a hair). The surplus which drains away is termed 'gravitational' water. In our experiment, the gravitational water collected in the beaker. We may be assisted in understanding the distinction between capillary and gravitational water if we think of a wet towel hung out to dry without first being passed through the wringer. Water dripping from the end of the towel is gravitational, that which remains after the drip ceases, capillary.

When we recall the relative sizes of sand and clay particles and the results of our experiments, we are able to say that the capillary tubes of small grained soils must have a total volume greater than that of the tubes in coarse kinds of soil. In the fine soils, the greater number of tubes more than makes up for their size.

Soil	Approximate weight of water that can be absorbed by 10 lbs. of dry soil
Humus	18 lbs.
Clay	6 “
Loam	5 “
Sand	2½ “

Water passing downwards through the soil finally reaches a layer of clay or hard rock which prevents its further descent. It gathers above this layer filling the soil to a certain level called the 'water-table'. The depth of the water-table below the surface changes from place to place depending upon the climate and the porosity of the soil. In swampy regions the water-table is at the surface, in dry districts it may lie at a depth of hundreds of feet. Rivers derive the greater part of their water by seepage from this vast storehouse.

Demonstration of how a water-table is formed.

Plan and carry out a simple classroom experiment to demonstrate the formation of a water-table.

Movement of moisture upward from the water-table.

Recall the upward movement of water in a towel suspended vertically with one end in water, and of oil in a wick.

The movement of tea upwards through sugar.

Place a lump of sugar in a few drops of tea. Note how the brown stain is seen to rise through the lump. Cover the top of the lump

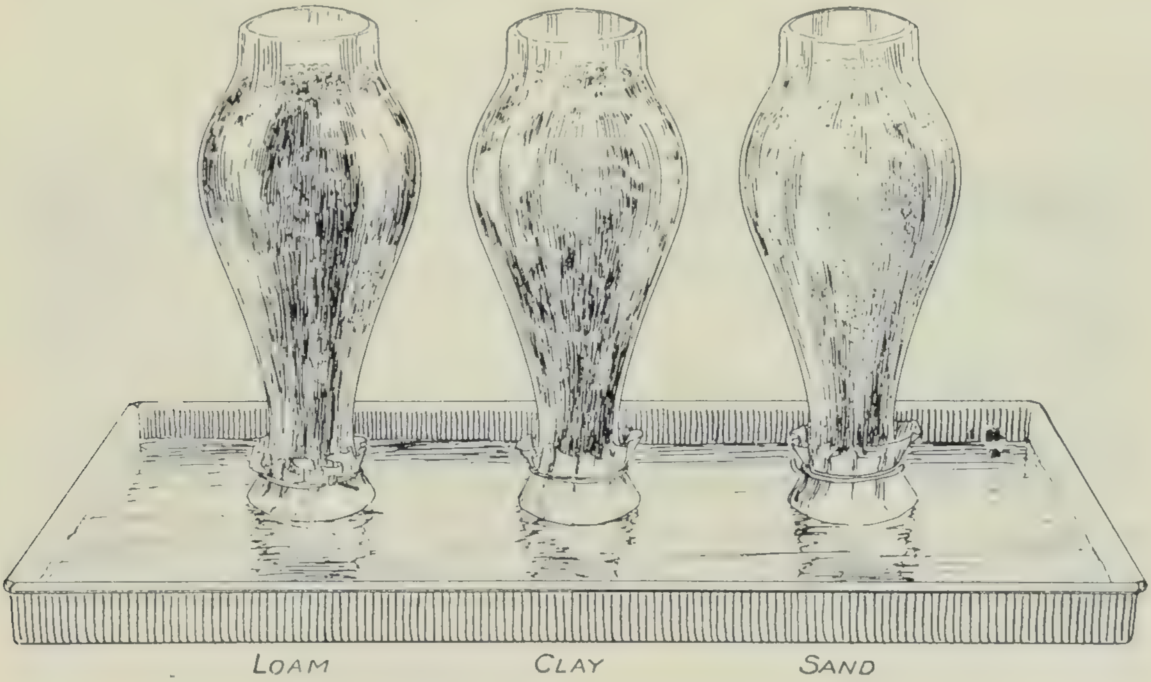


Fig. 196. Capillary action in soils.

with granulated or fine sugar. What effect has this loose sugar on the rise of the brown stain?

Devise an experiment to find if water will rise in a similar manner through a dry soil.

Comparison of different types of soil in respect to the upward movement of water through them.

Compare humus, clay, loam and sand in each of the following:—(a) rapidity of upward movement of water; (b) final height attained by the water.

Do you notice any relationship between the size of the particles and the final height? In which cases are the capillary tubes (a) largest (b) smallest?

If you were given three glass tubes with very fine bores of different sizes, what problem could you solve with their aid?

Just as water rises in a towel, in a piece of sugar or in a glass tube of very small bore, so it does through soils. In the coarse-grained sandy soils, the rise is small compared with that in the fine-grained clay and humus.

During dry weather, water rises in this manner from the store below the water-table. Evaporation at the surface and loss of water through leaves may gradually increase the depth of this zone until it no longer serves as a source of supply.

(Courtesy Geological Survey of Canada.)

Fig. 197. Salt craters at Salt Springs, Alberta.

Conservation of soil moisture.

In farming, it is often necessary to reduce evaporation from the surface as much as possible. One way of achieving this purpose is to form by cultivation a dry layer of soil about three inches in depth. Capillary water has a slower rate of ascent through dry than through moist soil so that the formation of such a layer or 'mulch', as soon as possible after rain, tends to retain water in lower levels by sacrificing moisture at the surface. We are sometimes advised to "water our gardens with a hoe".

In districts of scanty rainfall, a procedure is followed which has for its purpose the using of two seasons moisture for one crop. A crop is grown only every other year. During the season of fallow, the field is kept in cultivation. It is deeply ploughed before the period of greatest rainfall so that the soil may provide the greatest possible storage for water. Afterwards, a mulch is maintained to check evaporation. Another advantage is that weeds are brought under control. By keeping the fallow free from all plant growth, the heavy loss of water through the leaves is prevented, a saving more important probably than that effected by the mulch.

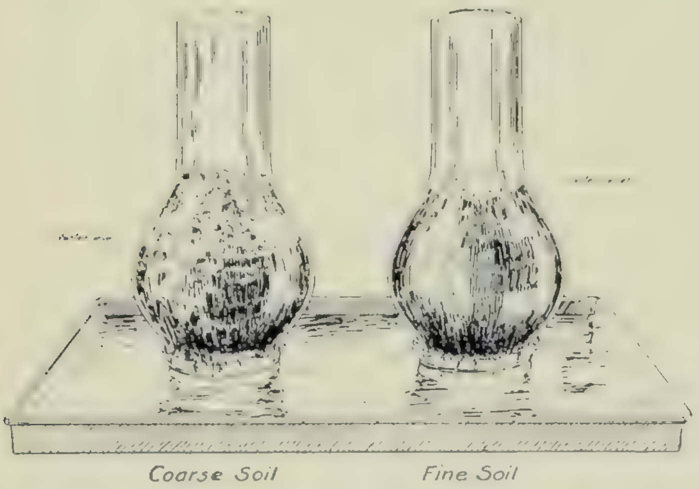


Fig. 198. The effect of pulverizing soil on the flow of moisture.

PROBLEM VII: Does soil contain air?

Bore holes in the bottom of a tin can (A). Place soil in this can and in another (B) which lacks the holes, until it is within a few inches from the surface. Tap the cans until the soil is packed as closely as in its original position in the garden. Add water quickly to B. Note what happens. Set A on a plate containing water. Then pour water quickly on the surface of the soil. Notice where the bubbles are formed in this case. Account for their production and location.

These are bubbles of air. Where is it held in the soil? Will a soil saturated with water contain air? Suggest a method for finding the volume of air in a sample of garden soil.

PROBLEM VIII: Of what value is soil air?

Very few crops grow well in soil filled with water. In such soils, no space is left between the particles for the air necessary for plant growth. In addition, the bacteria which reduce humus to a condition in which it is suitable for plant food do not thrive in a soil lacking air. It is estimated that a productive soil should contain air to the extent of 25 to 40 per cent of its volume. Soils may be aerated by tillage and also, by under-drainage. The part played by earthworms and insects in opening up the soil to air is of importance. Soil suited to agriculture does not consist merely of rock wastage. In addition, it contains humus, water, air, and living organisms.

PROBLEM IX: How does soil become exhausted?

If water which has seeped through soil be evaporated, a residue consisting of soluble substances very important as plant food will be found. Loss of this food through the action of water is termed ‘leaching’. Sandy soils which give ready passage to water are most liable to leaching. By adding humus and so increasing their power of holding water, the loss is reduced.

On slopes, there is danger of the removal of valuable soil by water running off the surface after rain. This loss is small if the hillside is wooded, but if the land is cultivated, and especially if it is ploughed in the direction of the slope, wastage occurs.

In very dry regions, a serious loss is caused by winds. Soil drifting has been fought by the growth of wind-breaks. By means of ‘strip cultivation’, the smothering of crops has to some extent been avoided. Increased pasturage seems to provide the best solution for this problem in the most afflicted areas.

Continuous removal of crops without the return of manure or fertilizer to the soil has been well-termed 'soil mining'. Just as the lifetime of even the largest mine is limited, so the fertility of the richest soil farmed in such a manner is finally exhausted.

TOPIC VI—PLANT LIFE

UNIT 9. MAJOR STUDY: The living cover of the earth is an important part of man's environment.

A. MINOR STUDY: There are many relationships between plants and man.

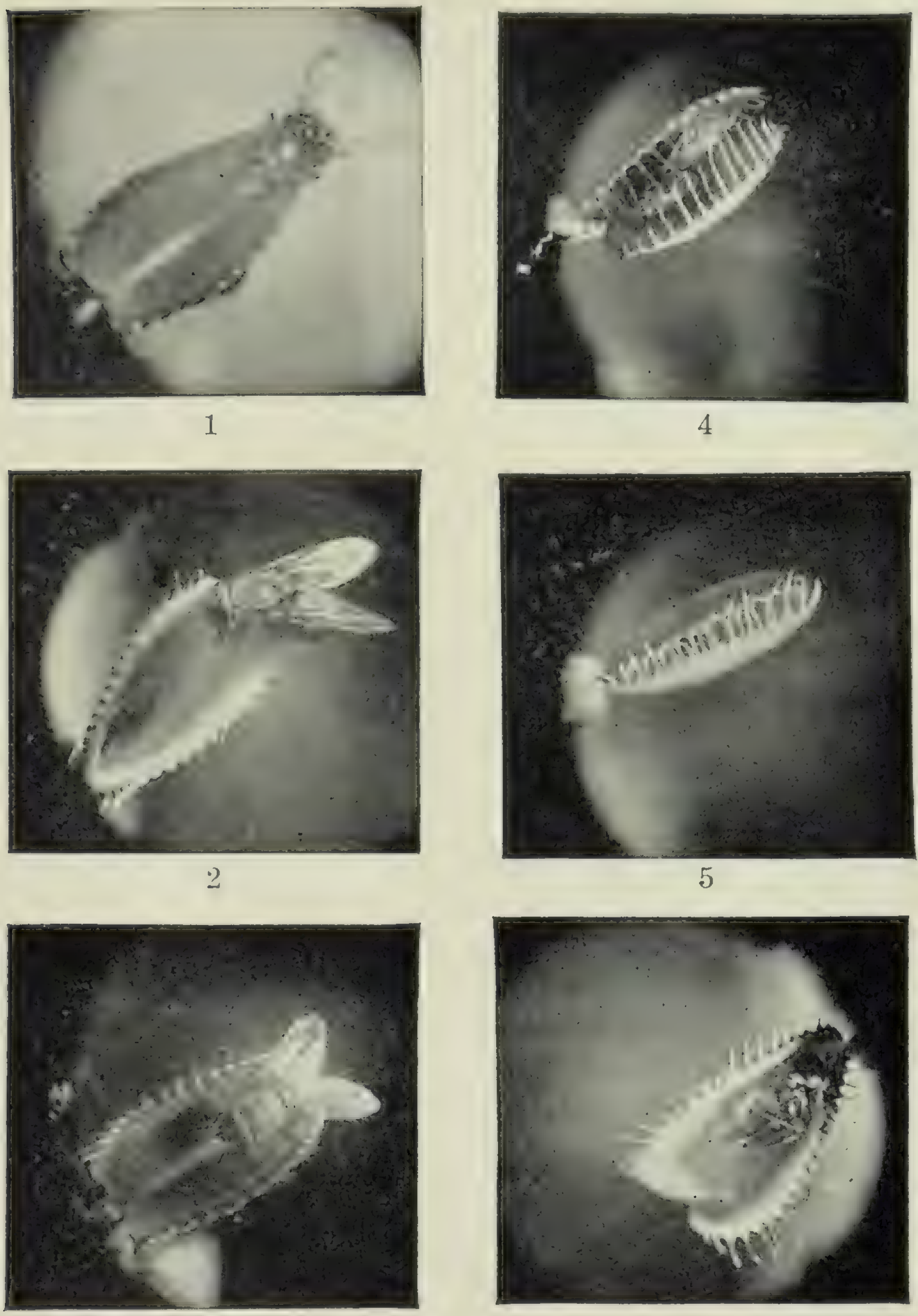
PROBLEM I: Are all creatures dependent on plants?

The story is told of two young men who went into the woods and, with the aid of a jack-knife and fishing equipment, tried to live "off the country" for a month. It is said that the attempt was abandoned after a few days because berries were unsatisfying, fishing was poor, and squirrels were active. If the youths were town-bred, it was brought home to them that the food of men living under more or less primitive conditions does not come wrapped up in neat cardboard packages or sealed tins, but rather that it is directly obtained from plants and animals.

Everything that we use as food, with the exceptions of table salt and water, is of plant or animal origin. The animals whose flesh we use are, in the main, plant-eating, or as we say herbivorous. Thus, directly or indirectly, we are dependent upon vegetation for our existence. You may object to this and say that we often eat fish which feed upon other fish. But, if the diet of these preyed-upon fish be examined, it will be found to consist of water-plants or animals which themselves live on aquatic vegetation. Human beings and animals of every kind could exist for only a very brief period if no plants were available.

PROBLEM II: What are some important food plants?

The five most important food plants of the world are believed to be wheat, rice, potatoes, oats, and maize or Indian corn. Wheat plays so important a part in the economic life of Canada that we are likely to forget the place of rice as a



1 4

2 5

3 6

(*Courtesy of the Gen. Biol. Supply House and Mr. Leon Keinigsberg.*)

Fig. 199. The Venus Fly-trap in operation: a strange instance of the interdependence of plants and animals.

Photograph No. 1 shows a house-fly alighting on the leaf. Then, the leaf closes and the plant absorbs nourishment from the dead insect. Photograph No. 6 shows the leaf opening and the undigested parts of the fly being ejected.

basic cereal of the teeming millions of the monsoon regions. With the exception of the potato, these plants are members of our most valuable plant family, the grasses. Other members of this family are barley, rye, millet and sugar cane. Then there are the hay and pasture grasses essential in the feeding of horses and cattle. Examples of these are prairie wool, timothy, Kentucky blue grass, Canadian blue grass and western rye grass. It is estimated that the annual income derived from hay and pasture grasses in Ontario exceeds the gold production of that province.

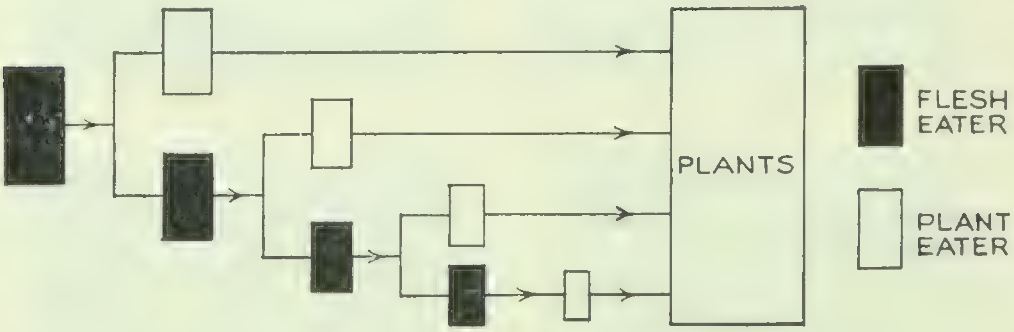


Fig. 200. All creatures are dependent on plants.

Only one of our grain plants, namely maize, originated on this continent. Wheat and barley have been grown for more than four thousand years and are believed to be natives of south-western Asia. Oats were grown in the days of the ancient Greeks and Romans, but it is thought that as a cultivated plant it is not as old as wheat and barley. With the exception of western rye grass, which is a native, all our more satisfactory pasture grasses originated in Europe or Asia.

The potato yields so well under suitable conditions that it can support more people per acre than any other crop. Both the potato and its relative the tomato came originally from South America.

Peas, beans, the clovers and alfalfa belong to the family called legumes. Later, it will be learned why the members of this family have a most helpful effect on the soil. Peas and beans, because of their high food value and relative cheapness, are sometimes called the poor man's steak. The field pea, which has not been long under cultivation, is found growing wild in countries of the Mediterranean basin. Garden peas, considered to be natives of Asia, have been cultivated for over two thousand years. Clovers and alfalfa are most nutritious foods for stock, and are native of Europe or Asia. Alfalfa was highly regarded by the Persians as fodder for horses and was brought by their invading armies to Greece about 500 B.C.

Most of our fruits and vegetables are natives of Europe, Asia or North Africa; one cannot help being impressed with the small contribution of the New World to the number of food plants. To Australia and New Zealand we are indebted chiefly for a variety of spinach.

PROBLEM III: How do plants provide us with clothes?

If we were suddenly deprived of cotton, rayon and linen, a grave industrial problem would arise. Some countries would be greatly benefited, others financially crippled; fashions in clothes would undergo a revolution. These three commodities which have so much to do with the livelihood and personal comfort of vast numbers of people are of vegetable origin.

Linen, woven from the long tough fibres by which the slender flax plant is enabled to stand erect, has had a long history. In ancient times, fine linen was considered worthy to be the gift of kings. There is doubt concerning the original home of flax, but we know that linen was highly prized in Egypt at an early time. Linen bandages, used for wrapping around mummies forty centuries ago, are still in existence. We read in the Bible of Solomon's importation of linen yarn from Egypt. Although its beauty, durability and coolness are still highly prized, linen has been replaced to a large extent by its cheaper rival, cotton. Neither flax nor cotton is a member of the grass family.

Linen, as we have seen, is made from fibres in the flax straw. Raw cotton, on the other hand, consists of a fine hairy outgrowth on the seeds of the cotton plant; man has made to serve his own purposes the device by which the plant provides for the dispersal of its seeds. It would appear that cotton was cultivated in India long before the Christian Era. When

Christopher Columbus discovered the New World, he observed that cotton grew in abundance and that from it the Indians were able to make cloth.

The rapid development of the manufacture of rayon or artificial silk in modern times is astounding. A great new industry has sprung up and the wardrobes of millions have been transformed. Rayon is made from cellulose, a substance built up by plants, and which, in a very pure form, may be seen in the best kind of filter paper. Large quantities of wood pulp are used annually in the production of this artificial silk.

PROBLEM IV: Can you add to this list of valuable plant products?

A detailed description of the vast number of useful substances directly or indirectly obtained from plants would fill many books. Here it is possible to give only some of the more important products. Coal and peat are included in the list because they are formed from plants which grew in past ages. There is much dispute concerning the origin of petroleum from which gasoline, lubricating oils, and other valuable articles of commerce are made. Many believe that petroleum has been formed from plants and animals of a remote period.

1. **Food.**
    (a) For man, e.g. cereals, garden vegetables, fruits, sugar (from beet, sugar cane and hard maple), cocoa, chocolate. (Tea and coffee have very little food value but are mildly stimulating.)
    (b) For domestic animals, e.g. the grasses and clovers.
    (c) For wild animals of economic importance, e.g. plants are essential for the existence of the varying hare, itself a necessity of life for certain valuable fur-bearers; also, the fisheries of the world are ultimately dependent upon small aquatic plants.
2. **Clothes.**
3. **Ropes, mats and bags.**
    These are made from hemp, jute, coco-nut fibre and various grasses.
4. **Lumber.**
5. **Fuel.**
    (a) Wood; (b) coal; (c) peat.
6. **Drugs.**
    e.g. tobacco, quinine. Many drugs are now made from tar which is produced as a by-product in the manufacture of gas from coal.

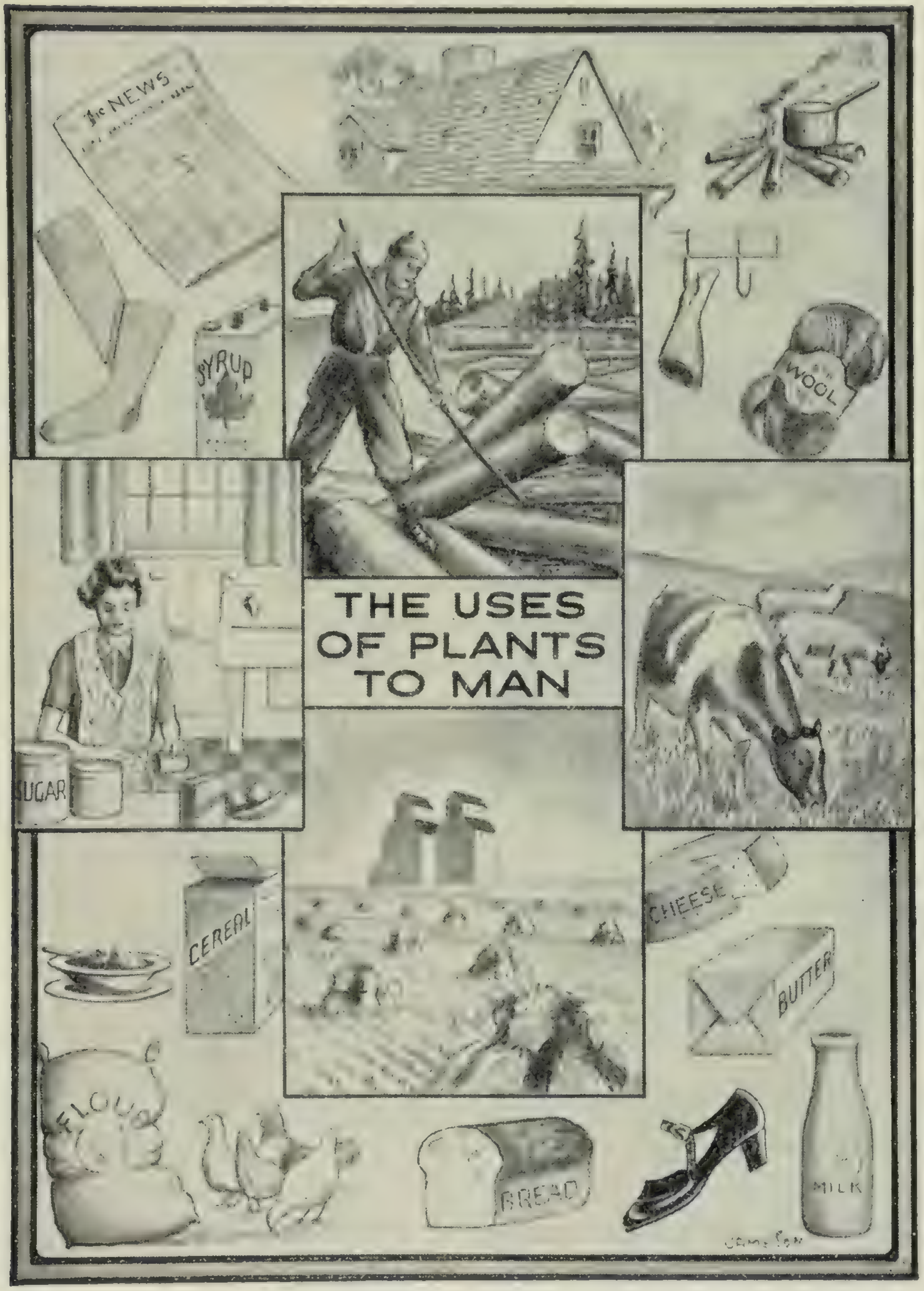


Fig. 201. Make a record of products, directly or indirectly derived from plants, which you have used in one day.

7. **Paper.**

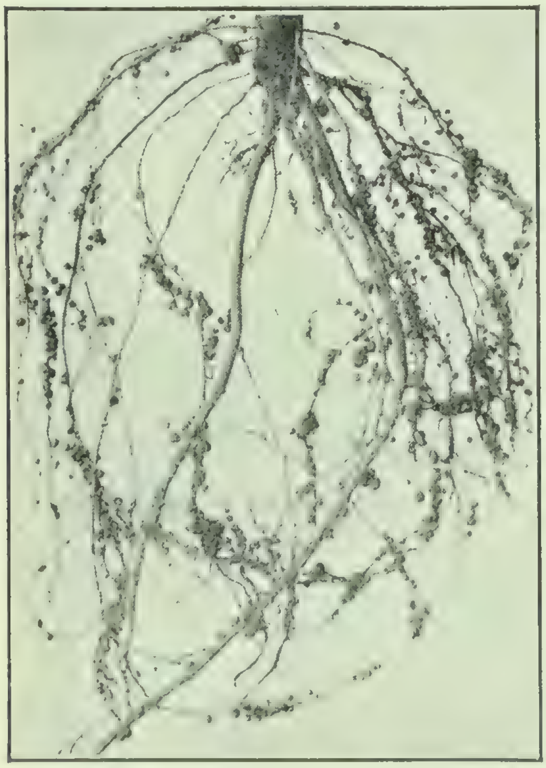
Much paper is made from the wood of coniferous trees. Supplies are also obtained from the waste of hemp, cotton and linen. Esparto grass and the straw of rye, wheat, barley and oats are often utilized.

8. **Rubber.**

Rubber is made from the milky juice of certain tropical plants.

9. **Fertilizer.**

Straw is a useful constituent in farm manure. Crops such as clover, soy bean, buckwheat and rye are frequently ploughed under to enrich the soil.



(Courtesy U.S. Dept. Agr.)

Fig. 202. Nodules on roots of the soy bean. These contain certain bacteria which enrich the soil.

10. **Oils.**

e.g. olive oil and palm oil which are used in the manufacture of soap; linseed oil and its inferior substitutes, hempseed oil and sunflower oil, are ingredients in paint.

11. **Resins.**

These are used in the manufacture of varnishes.

NOTE: When the bark of a pine tree is cut, a thick gum-like substance covers the cut. When this hardens it is called a resin. The resin from pine trees is called balsam. From this substance we obtain turpentine.

12. **Tanning material.**

In leather-making a substance called tannin is necessary. This is obtained from the bark of certain trees, for example, oak, birch, willow, hemlock and larch.

13. **Ink.**

By their activities certain insects cause little growths, known as galls, to form on certain plants. Those formed on the oak are often employed in the manufacture of ink.

14. **Explosives.**

Wood pulp and coal-tar are raw materials from which many explosives are made. It should be remembered that explosives are used in mining and engineering as well as in war.

15. **Alcohols.**

    (a) Ethyl alcohol is produced from corn, rye, barley, grapes, potatoes, apples, etc. It is used in chemistry, in medicine, and in the liquor trade.

    (b) Methyl alcohol, which is prepared from wood, finds use in chemistry and as a fuel.

16. **Dyes.**

    e.g. indigo, alizarin, and logwood. (The vast majority of dyes are now made from coal-tar.)

17. **Perfumes.**

    (Most perfumes, even those with names suggestive of a floral origin, are now made from coal-tar.)

18. **Flavouring materials.**

    That apparently uninteresting but chemically wonderful substance, coal-tar, is the source of many of our flavouring materials, for example, vanilla and oil of wintergreen. Even maple flavouring may be manufactured from tar.

19. **Celluloid.**

    This is made from wood pulp and is used in the manufacture of toys, toilet articles, and a great many other products.

20. **Artificial leather.**

    This is also a wood pulp product.

21. **Cork.**

    Cork is obtained from the bark of the cork oak.

22. **Linoleum and oil cloth.**

    Linoleum is made from a mixture of linseed oil, colouring matter, and cork dust on a canvas backing. Oil cloth consists of a fabric carrying a number of coats of paint.

PROBLEM V: How are some plants harmful?

In view of our emphasis on the benefits derived from plants we are apt to overlook the fact that there are many which cause financial loss, suffering, or even death. There are the weeds which steal from the farmer's profits and impose extra labour upon him. Some, like the horsetail and loco weed, are responsible for even the death of livestock.

It is doubtful if we should include in our list of harmful plants those from which narcotic drugs are obtained; man has himself to thank if they are the means of his ruin. Many

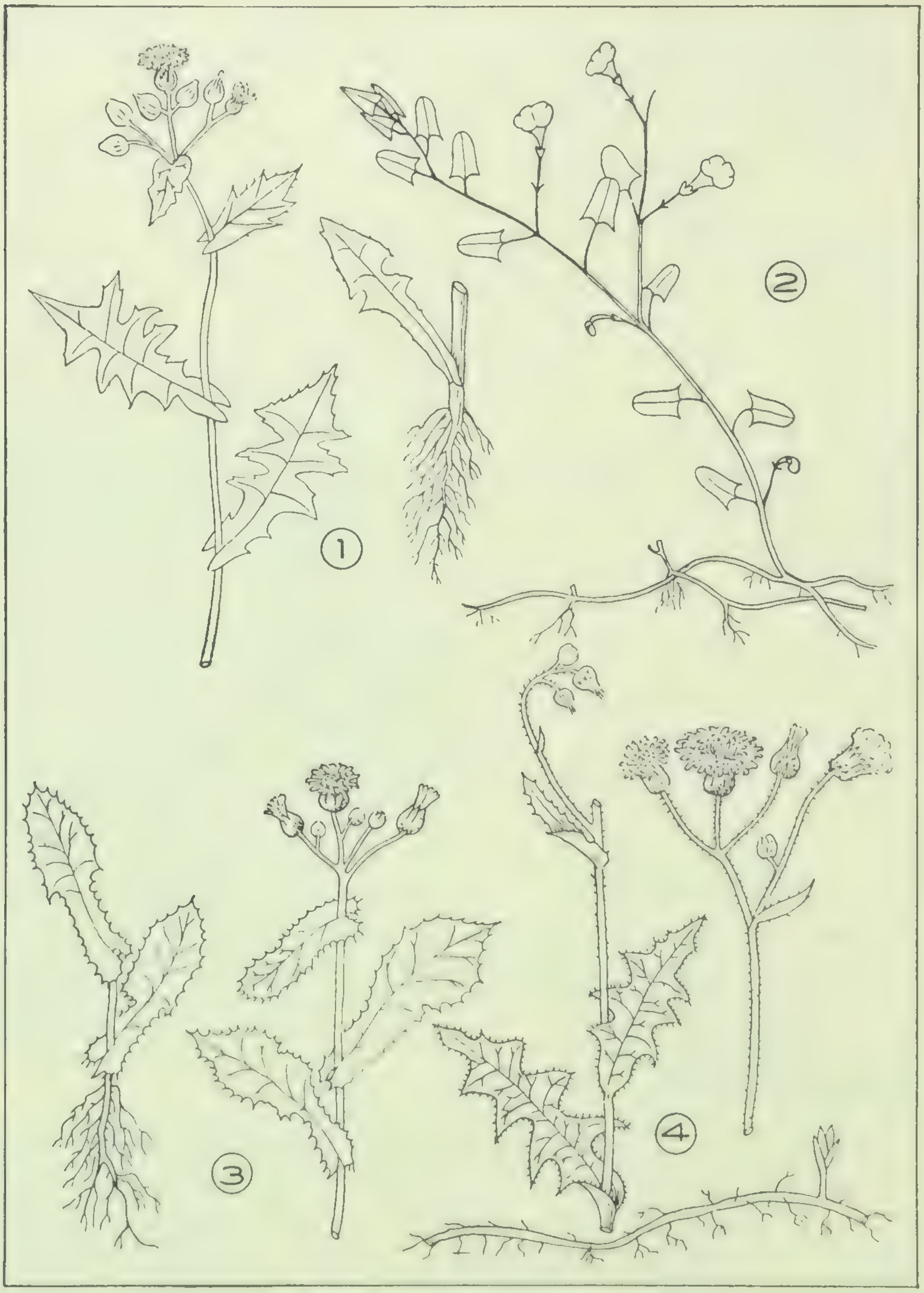


Fig. 203. Four harmful weeds.

(1) Common annual sow thistle. (2) Field bindweed
(3) Spiny annual sow thistle. (4) Perennial sow thistle.

diseases of men and animals are produced by those very small plants called bacteria, and losses amounting to millions of dollars are sustained annually in Canada from crop diseases caused by certain fungi which are themselves plants.

PROBLEM VI: **Have plants played an important part in history?**

Plants have been and still are a powerful influence in determining the course of affairs. A few scattered illustrative examples will be given.

Although grain has been grown for thousands of years, there are reasons for believing that in very early times man knew nothing of the art of cultivation. Where animals were plentiful he was a hunter. Living was often uncertain and the endless quest for food left little time for developing the arts and habits we associate with civilization. When food was scarce, he began to use edible grass seeds, collected probably by the women. Then, possibly by accident, it was discovered that the laborious search for these seeds could be avoided if some were scattered on a cleared place near the temporary dwelling. From such crude origin arose our present highly-developed grain farming. The early grain-growers were compelled to remain in a locality until the crop could be harvested. More permanent homes were established, household goods were gathered, and reserves of food were set up. Little groups of people came together and formed villages in order to have protection from thieves, and they began to learn something of the art of living together. It is believed that the greatest step towards the freeing of man from savagery was taken by the earliest growers of grain.

Much of early geographical discovery had as its motive the desire to find a seaway to India. Fortunes had been made by merchants in Venice, Genoa and Florence by importing spices (including pepper) and silk from the East. Western European countries looked enviously on the profitable trade but found their position on the Atlantic seaboard a disadvantageous one. The result was that in 1488 the Cape of Good Hope was rounded, and in 1497 India was reached by sea. Columbus, hoping to find a 'back door' to the east by sailing westward, discovered the New World in 1492. We recall that the desire to find a waterway to the East was responsible for a considerable amount of early exploration in Canada.

The introduction of the potato to Ireland led to considerable increase in the population of that island. Eventually, the potato blight, a disease caused by a plant belonging to the large group called fungi, caused serious damage to the crop. Failure of the principal crop brought much distress and great numbers of people died in 1847. Many hundreds of thousands came to North America in one of the greatest mass movements in history.

We need only refer to the development of cotton growing in the United States, the introduction of negro slaves, and the resultant Civil War. This again had its reflection in Britain. Shortage of cotton due to the Civil War and, in later years, to poor crops, caused much hardship in Lancashire where the manufacture of cotton goods was the principal industry. To avoid this dependence on cotton in the United States, attempts have been made to develop its cultivation in other parts of the world, particularly within the British Empire. Cotton is now grown extensively in India and in the Anglo-Egyptian Soudan. The success of cotton growing in Egypt and in the Soudan is dependent upon the flow of water in the Nile, so that for over thirty years Britain has been extremely interested in Lake Tana in Ethiopia, at the headwaters of the Blue Nile.

Another example of the influence of plants on the course of history may be seen in the flow of population to the Canadian west where cheap fertile lands made the growing of wheat a profitable enterprise.

Other instances may be supplied by the student from his reading in histories and the newspapers.

Exercises:

1. Make a list of articles in the room that are of plant origin.
2. Why is it that Canada which produces less wheat than the United States has a greater interest in the price of this commodity at

Liverpool? Name another country in a position similar to that of Canada.

3. Why do countries such as France and Italy encourage the growing of wheat by their farmers, although the cost of production is higher than in Canada and the quality of the flour is inferior to that of the Canadian product?
4. Give examples, other than those mentioned in the text, of the influence of plants on history.

ENRICHMENT SECTION, NUMBER 12.

Profitable herbs.

Medicinal plants and herb flavours are important factors in the drug, tobacco, and many great food industries.

Dandelion seed is sown in early spring, drilled in rows eighteen inches apart and thinned to one plant to the foot. The roots are dug in the fall of the second season after planting, washed and dried. Prices range from nine to eighteen cents a pound, the yield is around half a ton to the acre.

Catnip is a hardy garden herb in commercial demand for its leaves and flowering tops.

Horehound, a hardy leaf herb, grows as a common weed in many parts of the country.

Licorice is a dry weather herb native to California and the southwest where it is a weed pest. Roots are harvested at the end of the third year and the yield is as high as five thousand pounds of cured root to the acre. Prices range from five to twenty cents a pound.

Common sage is a hardy perennial herb used for both seasoning and medicines.

Peppermint, spearmint and wintergreen are the three most valuable of our native mints.

The larkspur is a garden flower which bears a seed used in remedies for external parasites.

Burdock is a large perennial. Both roots and leaves have a medicinal value.

Thyme is a shrublike, perennial herb used for seasoning, and for oil of thyme.

Exercises:

1. List other plants that you have good reason to believe are of medicinal value. (Hint: Think of the names of various medicines, as, quinine, extract of wild strawberry, ginger wine.)
2. Find the meaning of the word *condiment* in a dictionary. List as many condiments as you can. What is the source of each?

UNIT 10. MAJOR STUDY: How some common green plants are fitted for the struggle for existence.

When we speak of our necessities of life, we refer to air, water, food, and in the colder parts of the world, clothes and shelter. Since plants are living things, it is natural to ask if they too have certain needs which must be satisfied. In this unit we shall learn about the needs of green plants and how they are fitted for supplying them.

It is not enough that an individual, whether it be plant or animal, should be able to live for a time. There must be some means or other for ensuring continuance of the race. In addition to learning how plants secure a livelihood, we shall find out how they reproduce their kind.

A. MINOR STUDY: Water and plant life.

Plants require water.

From everyday experiences we can give numerous instances of the need of plants for water. Everyone has sprinkled a lawn or watered a potted plant and is familiar with the results which would follow if this were not done. The remarkable effect on the wheat crop of lack of rainfall is known to all.

A few simple experiments may be of interest.

Demonstration of the presence of water in plants.

(Recall experiments on page 57).

PROBLEM I: How does water enter the plant?

We who know that the water required by a plant enters its roots find it rather amusing to watch a child carefully spraying the leaves with the liquid. However, we are concerned, not so much with *where* the water enters, as with *how* it gains admission. It will assist us in understanding this process if we make some observations on roots and perform a few simple experiments.

Observation of root-hairs.

Place a few sheets of blotting paper on a plate. Moisten them thoroughly and over them scatter some radish or mustard seeds. Cover the plate and leave it in a warm place.

Using a lens, examine the roots of the seedlings. Do the hairs extend all over the roots? Where are they longest? How are root-hairs likely to be affected when transplanting in done? Make a drawing (x4) of a root. (NOTE: (x4) means four times its actual size.)

Examination of a root under the microscope.

By means of a sharp razor blade, make very thin transverse sections of the root of a seedling in the region of root-hairs. Select the thinnest section and place it on a microscope slide. Add a drop of iodine solution and examine the section under the low power. (The iodine stains the section, making it more visible.)

Notice the cells and their walls. Describe the appearance of a root-hair under the microscope.

(Iodine solution may be prepared as follows: Dissolve 10 grams of potassium iodide in water; then add 5 grams of iodine; stir thoroughly and make the solution up to 500 cubic centimetres.

NOTE: Iodine is very slightly soluble in water. The 'tincture of iodine' sold in drug stores is a solution in alcohol.)

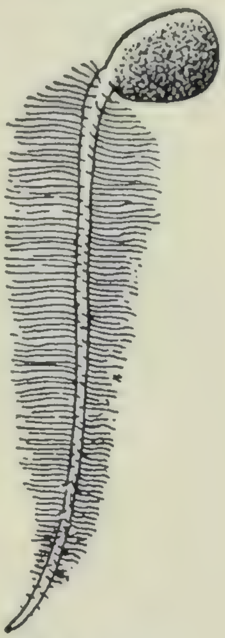


Fig. 204.
Seedling of mustard.

Most people have little idea of the size of the root-system of plants. Who would imagine that the roots of a cabbage plant may be traced through 200 cubic feet of soil, or that those of an oat plant may be as much as 154 feet in length? However, this is insignificant in comparison with the total length of the roots of a squash plant which has been estimated at 15 miles.

These lengths are due mainly to the presence of the root-hairs which are very numerous. Indeed, as many as 400 have been found on a single square millimetre. In growing, they make their way between the particles of soil, so that when a plant is moved many of the delicate little structures are injured. If the injury is too extensive, the plant dies. Temporary wilting may be observed while the plant is replacing injured root-hairs by new ones.

Now let us perform the experiments.

Experiments which will assist us in learning how water enters the roots of plants.

1. Soak some dried prunes in water over night. Next morning, compare their appearance with that of the unsoaked prunes. Account for the change. Is there any trace of discoloration in the water which surrounds the prunes? If there is, suggest a cause for it.

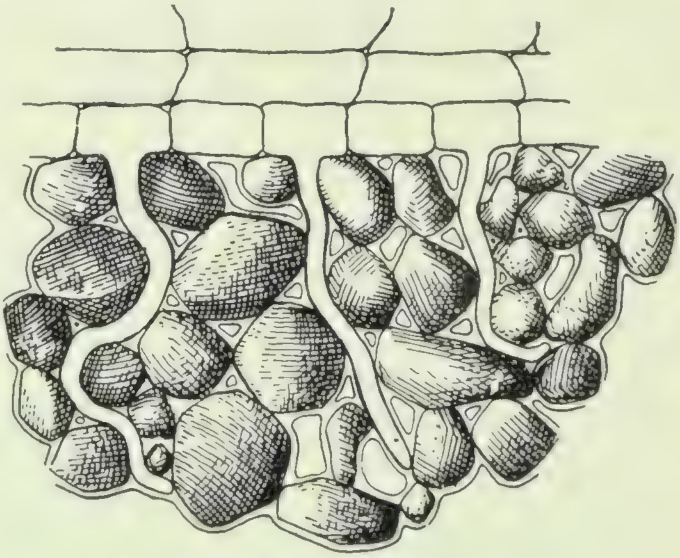


Fig. 205. Root-hairs in contact with soil solution.

2. Prunes contain some sugar, and are, as we see, surrounded by a skin. Let us make an artificial prune and try the effect of soaking it in water. Fill an egg cup with a strong solution of brown sugar. (Molasses is a convenient substitute.) A piece of animal membrane will serve for the skin of our artificial prune. Soak this until it is soft and then tie it tightly over the egg cup. Be careful to see that the egg cup is completely filled with the solution.

Wash the outside of this unusual fruit and place it in a beaker containing water so that the membrane is below the surface. Examine the shape of the membrane after an hour or two. Is there any evidence that the water has entered the egg cup?

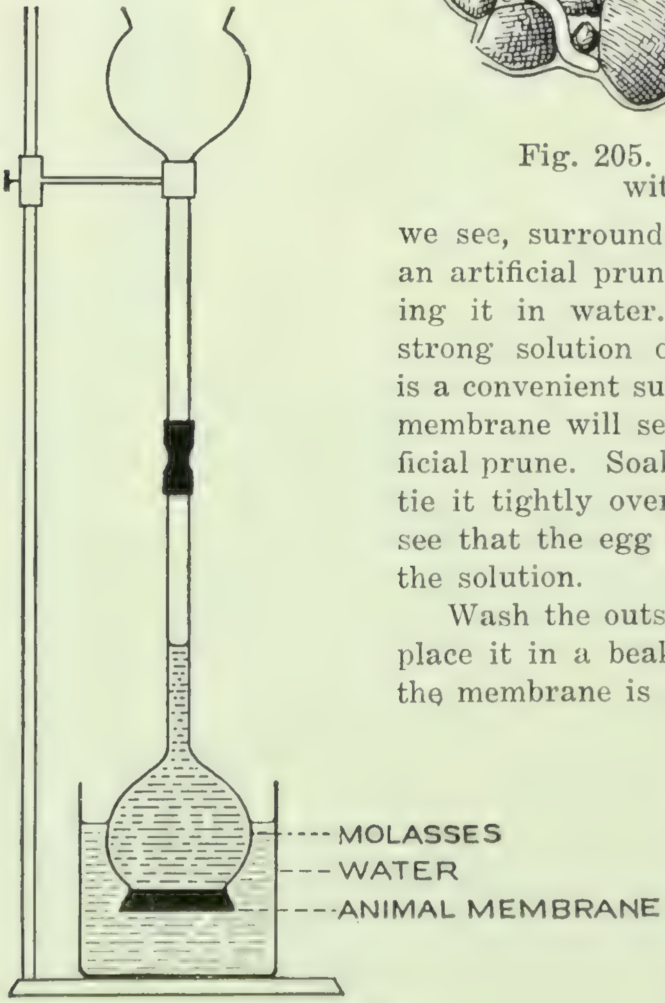


Fig. 206.

3. A modification of the above experiment is instructive. Tie the soaked membrane tightly

across the funnel of a thistle-tube. Pour in molasses or copper sulphate solution until it reaches about an inch above the narrow end of the funnel. Attach another thistle-tube to the one containing the molasses by means of a short piece of rubber tubing. Support this apparatus by means of a retort stand and allow the membrane to dip about an inch below the surface of water in a beaker. Mark the level of the molasses with a piece of gummed paper. Observe the height of the liquid occasionally over a period of about thirty-six hours.

Has water passed from the beaker into the thistle-tube? Has there been a transference of molasses to the beaker? What do you suppose would have been the result if, in the beginning, water had been placed in the tube and molasses in the beaker? Test this experimentally.

4. Take three fairly large potatoes, A, B and C. Cut across one end so that the tubers stand in an upright position. Remove the skin for about half an inch above the base and then, at the other end, make an excavation the sides of which are about half an inch thick.

Into potato A put some sugar, and into B and C a little water. Stand A and C in dishes containing water and B in one with a strong solution of sugar. In each case the contents of the dish should come just above the peeled part of the tuber. On the following day observe any changes that have occurred.

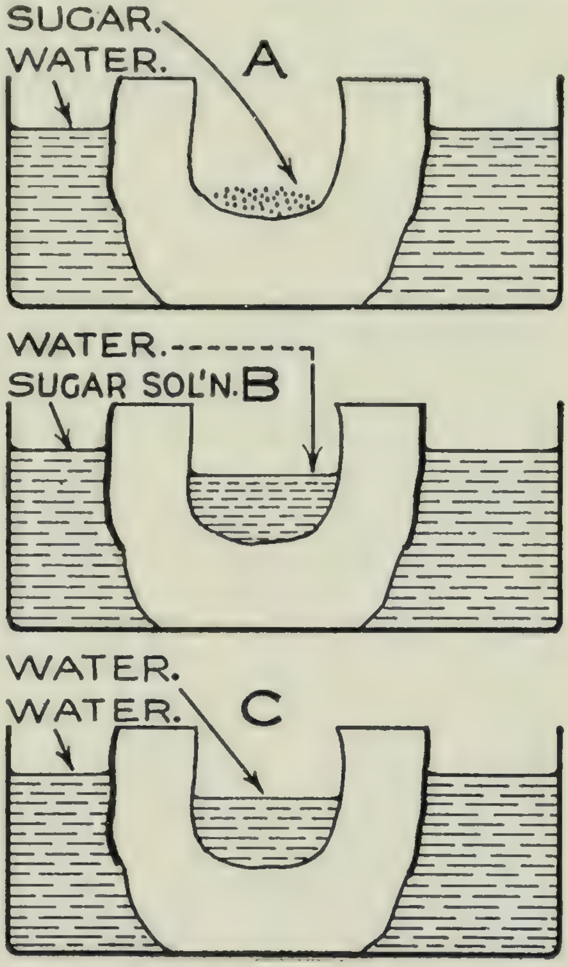


Fig. 207. Observe if any alteration occurs in the levels of the liquids in B and C. What purpose is served by C?

Potato	Contents of potato	Contents of dish	Observations
A	Sugar	Water	
B	Water	Sugar	
C	Water	Water	

5. Carefully remove the shell from a patch about the size of a five-cent piece at the broad end of an egg. Do not puncture the membrane.

At the other end remove a little of the shell and, without permitting the contents of the egg to escape, make a small opening in the skin. Place the egg so that the broad end is immersed in water. Prepare another egg in the same way and leave it in the same position as the first but without having the lower end dipping into water. At the end of twenty-four hours observe the eggs.

6. Cut strips of parsnip or carrot and notice their firmness. Place one in salt solution and another in water. After a time, observe any change in the degree of firmness of the strips. Now put into water the piece of parsnip that was originally in brine, and in its place lay the piece that was formerly in water. What are the results of this interchange?

Will a piece of boiled parsnip recover its rigidity if soaked in cold water?

We have seen that if water is separated from a solution by a membrane of plant or animal origin it passes through the membrane into the solution. Pure water is unnecessary because if there are two solutions, the one strong and the other weak, water passes from the latter to the former. This process is termed *osmosis.* (Gk. *osmos,* a push.)

In the case of the dried prune, water passed inward through the skin to the sugar. Also, a small amount of the contents of the prune left it and discoloured the water. When a piece of animal membrane separated molasses and water some of the latter entered to dilute the former. Furthermore, we observed that a little of the molasses passed into the water.

When sugar was placed in the hollowed potato, some water left adjacent cells and a strong sugar solution was formed. As these cells lost water, their contents became more concentrated than those of neighbouring cells. As a result, water passed to the cells next the sugar solution from those immediately behind them. These in turn obtained water from the cells on their other side. This process continued until the cells at the peeled portion of the potato were deprived of water. The outer layer obtained water from the dish. Thus, from the outer to the inner cells, water was passed on until the hollow in the potato was filled to overflowing. A reverse process occurred when the sugar was placed in the dish.

Now we are in a position to obtain a crude idea of how water enters roots. The root-hairs behave in somewhat the same manner as our natural and artificial prunes. Inside is cell sap; outside, the soil water. This water enters the hairs and passes on from cell to cell by osmosis, just as it travels through the potato. However, there is a difference between the animal membrane we used in our experiment and the protoplasm of the cells. A little of the molasses passed into the water. This does not happen, or only to a very limited extent, in the case of the protoplasm. Water enters, but cell sap does not move outward.

Exercises:

1. Account for each of the following: (1) salt is effective in killing weeds; (ii) when sugar is placed in strawberries, a coloured syrup is formed and the fruit loses its shape; (iii) when beans are being boiled, salt is added after, rather than before, they become soft; (iv) when celery is soaked in water, it becomes crisp; (v) fresh grapes shrink when placed in a strong solution of sugar.
2. When moving plants to a new position, why do we try to leave the soil undisturbed around the roots?
3. Give instances drawn from your observations or reading of the growth of roots towards water.

PROBLEM III: Does water follow definite paths in passing from the roots up through the stem?

Transportation of water in the stem.

Stand in water, coloured with a small amount of red ink or eosin, a leaf of celery, a geranium stem, and a twig of poplar. It is advisable to cut these under water to prevent air bubbles from entering. After a few days, remove the material from the solution and, with a sharp knife cut the stem across and lengthwise. Examine the sections with a magnifying glass. Trace the paths along which the water rose.

Passage of water through the stem to a flower.

Using a white flower, try to demonstrate the passage of water from the stem to the blossom.

The red stain indicates the route taken by the solution from the soil in moving upward. This liquid travels from the roots to the leaves through elongated thick-walled cells which make up what is known as the *xylem,* (Gk. *xylon,* wood). The diameters of these cells in trees vary from 1/2500 inch to 1/500 inch.

PROBLEM IV: How do plants get rid of surplus water?

As water makes up a large part of the weight of vegetable matter, at first it might be thought that all the liquid taken in is retained by the plant. However, since plants could not possibly contain the large volumes of water they are known to use we may wonder what becomes of the surplus.

How surplus water escapes from the plant.

Frequently we notice droplets of a colourless liquid on a window close to the leaves of a potted plant. It may be shown by tests that the liquid is water. What does this observation suggest?

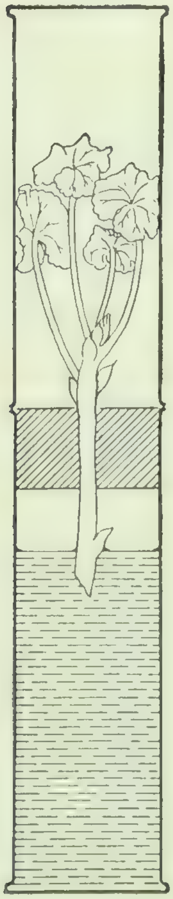


Fig. 208.

Experiment to demonstrate transpiration. Make a sketch of the apparatus for the control experiment.

Before reading the following instructions, try to plan and perform an experiment to prove the truth or falsity of your explanation.

(i) Set up the apparatus shown in Fig. 208. By means of wax, make the cork air-tight where it meets the glass and stem. Smear the rim of the jar with vaseline. Be sure that the upper jar is quite dry.

If someone suggested that, in spite of your precautions, water vapour might have escaped past the cork, how would you attempt to answer the objection experimentally?

(ii) It may be objected that we did not use a whole plant. Thoroughly water the soil in which a small potted geranium is growing. Cut a sheet of rubber in the shape of a circle. The radius should be about two inches longer than that of the upper part of the pot. Make an incision to the centre along a radius. Fasten the sheet tightly across the top of the pot and join the cut parts by means of rubber cement or adhesive tape. Try to ensure that water vapour cannot escape from the soil where the rubber surrounds the stem or through the hole in the bottom of the pot. Cover the plant and pot with a dry bell-jar the rim of which has been smeared with vaseline. Is a control (or check) experiment necessary? If it is, plan and perform one.

Water enters the roots of plants in the form of liquid and most of it is given off from the leaves as vapour. In its passage, it carries certain substances needed by the plant for its development. Some idea of the quantity of vapour given off or *transpired,* may be gained from the following figures: in twenty-four hours one cabbage plant transpired 2½ pints of water, and an acre of pasture grass, 106 tons; on a hot day a birch tree gave off 3½ to 4½ tons; within twelve hours an elm released 7¾ tons. The amount transpired depends not only on the kind of plant but also on the locality, the soil and the weather.

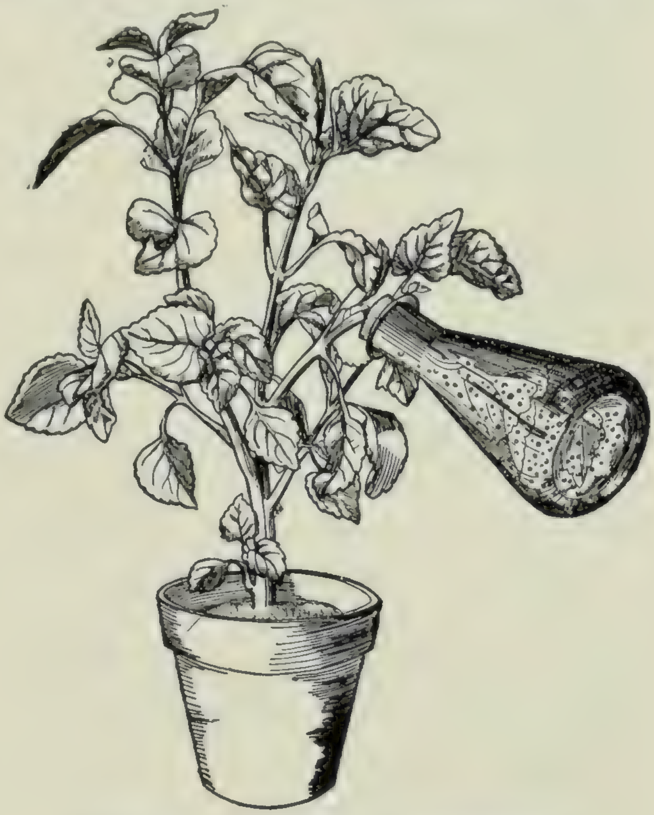


Fig. 209. Another experiment to demonstrate transpiration.

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PROBLEM V: In what way is a leaf fitted to perform the work of transpiration?

Recall experiment on page 98.

Examination of the skin of a leaf.

We have seen that the skin of a leaf is pierced by openings or stomata. They are extremely small, having an average area of about one-millionth of a square inch; their total area is about one-seventh of the leaf's surface. Through these pores the water vapour passes out of the leaf.

On most leaves, the stomata are more numerous on the underside than on the upper. The sunflower leaf has about 200,000 per square inch on the lower surface, 100,000 on the same area of the upper, and a total of about 13,000,000 in all. On the upper side of birch, lilac and peony leaves, and on the lower surface of a water-lily leaf, there is none. Roughly speaking, they are equally numerous on both surfaces of vertical leaves; the iris leaf, for example, has about 12,000 stomata on each side.

A way of finding where the stomata are located.

Remove a large leaf from a plant and seal the end of the leaf-stalk with wax. Hold the blade in warm water. The heat causes gas between the cells in the spongy tissue to expand. It emerges from the pores and forms the little bubbles which may be observed on the leaf.

If a plant were to give off more water in transpiration than it could obtain from the soil, the leaves would lose their rigidity, or, as we say usually, wilting would occur. This is a condition frequently seen on hot summer days and also when root-hairs are injured during transplanting. Should wilting continue too long, the plant will die. On either side of each stoma is a sausage-shaped cell containing chlorophyll. (See Fig. p. 307). These *guard cells,* as they are called, tend to close the stomata whenever transpiration becomes excessive, and there is danger of wilting. The compact layer of cells forming the epidermis of the leaf and also the waxy cuticle which covers the epidermis are of service to the plant in preventing excessive loss of water vapour.

B. MINOR STUDY: Mineral salts and plant life.

We have learned how one of the plant's necessities of life, water, enters the root-hairs and how surplus quantities escape in gaseous form through the stomata. Now, we shall give our attention to other substances found in vegetable matter.

PROBLEM I: What residue is left when vegetable matter is strongly heated?

Place on an iron spoon a small quantity of one of the following: wood, rolled oats, wheat flour, geranium stem, corn stalk. Heat in a flame until no further change can be detected.

Is there any substance left which you are unable to burn? Describe its appearance. This residue consists of mineral matter.

What use of wood ashes was made by the pioneers in densely forested parts of Canada?

Chemists find in plants a number of substances, for example, calcium, magnesium, phosphorus and sulphur. (All of us have been made familiar with the fact that spinach contains iron.) The question as to how these substances are obtained by the plant now arises.

PROBLEM II: How does the green plant obtain mineral substances?

We are aware that soil water gains admittance to the plant through the root-hairs. There is a possibility that the mineral matter is dissolved in this water. Let us examine some water which has been in contact with soil in order to find out if it contains dissolved material.

A property of soil water.

Shake together some soil and tap water. Filter a small volume of the muddy water and collect a little of the filtrate, or water that comes through, on a watch-glass. Cover this loosely and leave it in a warm place.

Let us suppose that after the water evaporated a substance remained on the glass. Could we say with certainty that it was derived from the soil? Suggest a possible origin for such a residue.

Clearly it is necessary that we should perform a control or check experiment. Pour on a watch-glass a quantity of tap water equal to that used previously. Place a loosely-fitting cover on the glass; then leave it beside the other. To avoid confusion, label one of the pieces of apparatus.

When the liquid has evaporated from both glasses, examine them carefully and find out if the water which had been shaken with soil contains more substance than that which came directly from the tap or well.

It would be much more conclusive to use the following procedure: shake distilled water or rain water thoroughly with dried soil, filter the muddy liquid and permit the filtrate to evaporate. Even if he used distilled water, a cautious person would carry out a control experiment. Why is this desirable?

Soil consists largely of insoluble particles between which are little spaces; into these openings air and water enter. When the latter encounters soluble materials, a weak solution is formed. From this solution the plant derives the nitrogen, sulphur, calcium, iron, magnesium and potassium which it requires.

It is needless to remind anyone who has ever seen or taken tonic containing iron or calcium that the metallic form is not present. When the metal is combined or united with other substances, it forms compounds of which some are soluble in water and others insoluble. Only those that are soluble can be absorbed by a plant.

Culture solutions.

It is possible to grow plants without having their roots in soil. Tons of tomatoes have been harvested by experimenters from plants grown in water in which the needed materials were dissolved. The following is a formula for a culture solution:

Ingredient	Quantity	Necessary substance present
Calcium nitrate	1.0 gram	Calcium and nitrogen
Potassium phosphate	0.2 "	Potassium and phosphorus
Potassium nitrate	0.2 "	Potassium and nitrogen
Magnesium sulphate	0.2 "	Magnesium and sulphur
Ferric chloride	Trace	Iron
Distilled water	1000 c.cm.	

The effect of depriving a plant of a needed element.

Wash carefully with distilled water five jars of about half a pint capacity. Number the jars 1 to 5 and place in them distilled water, full culture solution and solutions from which a substance is missing.

1	2	3	4	5
Distilled water	**Full culture solution**	**Calcium out**	**Nitrogen out**	**Iron out**
		(Substitute potassium nitrate for calcium nitrate in formula.)	(Substitute calcium chloride for calcium nitrate and potassium chloride for potassium nitrate.	(Omit ferric chloride.)

Fit the jars with a cork or cardboard disc from which has been removed a portion large enough to admit a small plant. The roots of five similar seedlings should be washed and then thoroughly rinsed in distilled water. Place the plants so that their roots are immersed in the liquid and put cotton batting in the opening of the cork to support the plant, reduce evaporation and exclude dust. Wrap black cloth or paper around the jars and leave them in a warm sunny place. By means of a bicycle pump attached to a piece of tubing, force air through the liquids every day. When doing so, take care that there is no transference of solution from one jar to another. Add more solution when necessary.

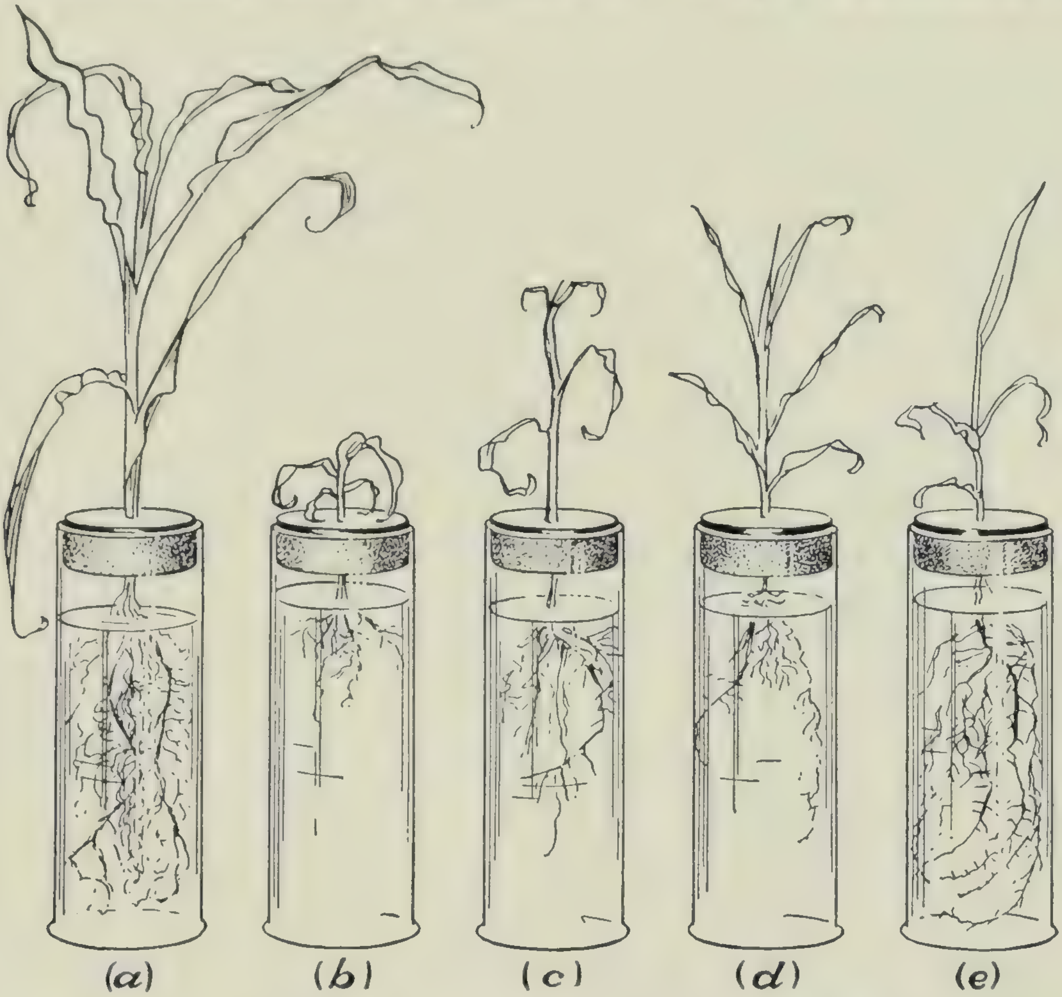


Fig. 210. Corn plants growing in solution. (a) All necessary substances present. (b) Nitrogen lacking. (c) Calcium lacking. (d. Phosphorus lacking. (e) Potassium lacking.

(*Redrawn by permission from 'Earth and Man'—Andrade and Huxley. Basil Blackwell. McClelland & Stewart.*)

Observe the development of the plants. In which case is the most satisfactory growth maintained?

Although it is much easier to describe than to carry out these experiments satisfactorily, they are worth an effort.

C. MINOR STUDY: The plant as a food factory.

Other substances besides water and mineral salts are found in plants. We shall learn how to test for the presence of one of these.

How to test for the presence of starch.

Add a drop or two of iodine solution to some starch paste. Observe the change in colour. Is this colour produced when iodine solution is added to sugar? Whenever the addition of iodine solution to a substance gives rise to a blue coloration, the presence of starch is indicated.

Test with iodine solution a cut surface of each of the following: an onion bulb, a dandelion root, a turnip, a bean seed, a pea seed, a corn grain, a wheat grain, an acorn. Which of these contain starch?

PROBLEM I: Do leaves contain starch?

It would be of interest to know if starch is found in leaves. However, there is a difficulty. If starch were present, the green colouring matter called chlorophyll (or leaf-green) would obscure the effect of the iodine. Hence, before the test can be performed, it is necessary to remove the chlorophyll. We know from experience that boiling green vegetables in water is insufficient to remove the green colour. Some other plan must be adopted.

Removal of chlorophyll from a leaf.

Immerse a leaf for a few minutes in boiling water in order to kill it. Float on hot water an evaporating dish containing a small quantity of alcohol. Place the leaf in the alcohol. In order to extract the chlorophyll quickly it may be necessary to re-heat the water. While this is being done, the dish should be removed from the neighbourhood of the flame because alcohol vapour is highly inflammable.

Remove the chlorophyll from the leaf of a plant which has been exposed to sunlight for several hours. Test for starch.

No doubt you have remarked on the suggestion that leaves *which have been exposed to light* should be tested for the presence of starch. One or two simple experiments will show why this was necessary.

PROBLEM II: Is starch present in leaves which have been kept in darkness?

(i) Place in a dark cupboard for twenty-four hours a plant the leaves of which contain starch. Can you detect starch in one of the leaves at the end of this period?

(ii) With thin pieces of cork fastened by pins cover both sides of a leaf attached to the plant. This, of course, will prevent the access of light to the part covered. Leave the plant in sunlight for a few hours and test for starch, (a) the leaf which has been kept covered, (b) a leaf which has been exposed to light. An interesting modification of the experiment is to use, instead of cork, a piece of lead foil from which the pupil's initials have been cut. Is starch found in leaves which have been kept in darkness? Is it present in leaves which have been exposed to sunlight?

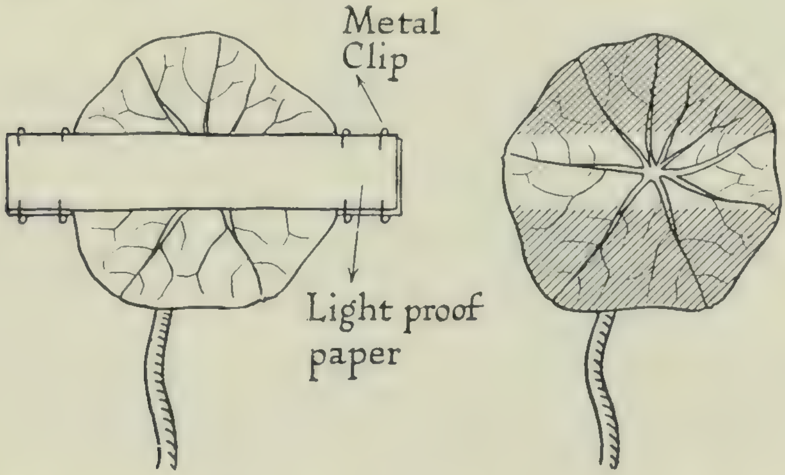


Fig. 211. Starch was formed in the part of the leaf exposed to sunlight but not in that covered by light proof paper.

Phototropism.

Sow grass seed in a flower-pot. Leave the pot near a window and notice the direction in which the young plants grow. It is interesting to use several pots and to place them at different distances from the window. This bending of plants towards the light, which is familiar to all who grow geraniums indoors, is given a long name, *phototropism.* (Gk. *phos*, light; *tropos*, a turn.)

You have learned that leaves which have been exposed to sunlight contain starch and also that this substance disappears when the plant is kept in darkness. In leaves, and in green plants like pondscum, is a substance called chlorophyll. Has this green pigment anything to do with the existence of the starch?

PROBLEM III: Is there any connection between the presence of chlorophyll and that of starch?

Take a leaf of a coleus or a variegated geranium plant which has been exposed to sunlight for several hours. Make a drawing of the leaf which shows the parts in which chlorophyll is lacking. After removing the chlorophyll from the leaf, test for starch, and, when the colour develops, compare the leaf with the drawing. Is starch present in the region which was green originally? Is it present in the part which did not contain chlorophyll?

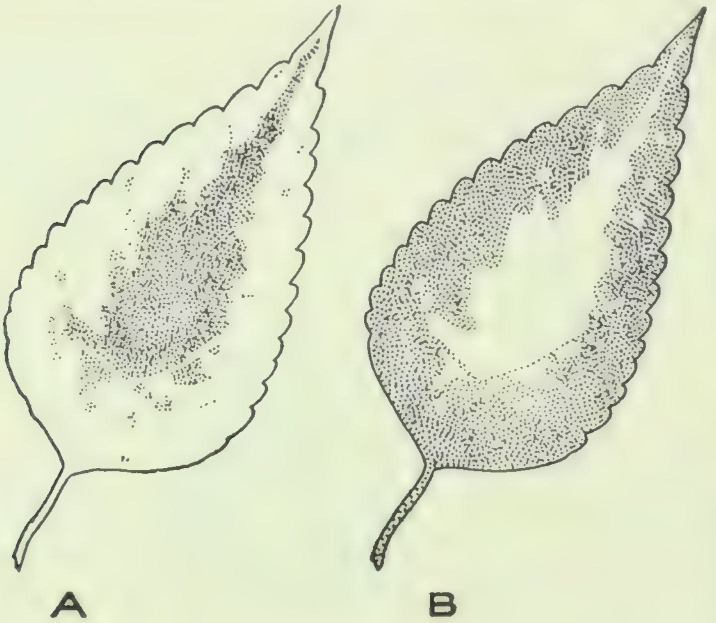


Fig. 212. Coleus leaf. (A) Shaded portion is the part lacking chlorophyll. (B) Shaded portion is the region in which starch was found.

A look inside a leaf.

Most leaves are so thin that it is difficult to imagine anything very wonderful or complicated between the two faces. Yet, it is worth while to examine the interior.

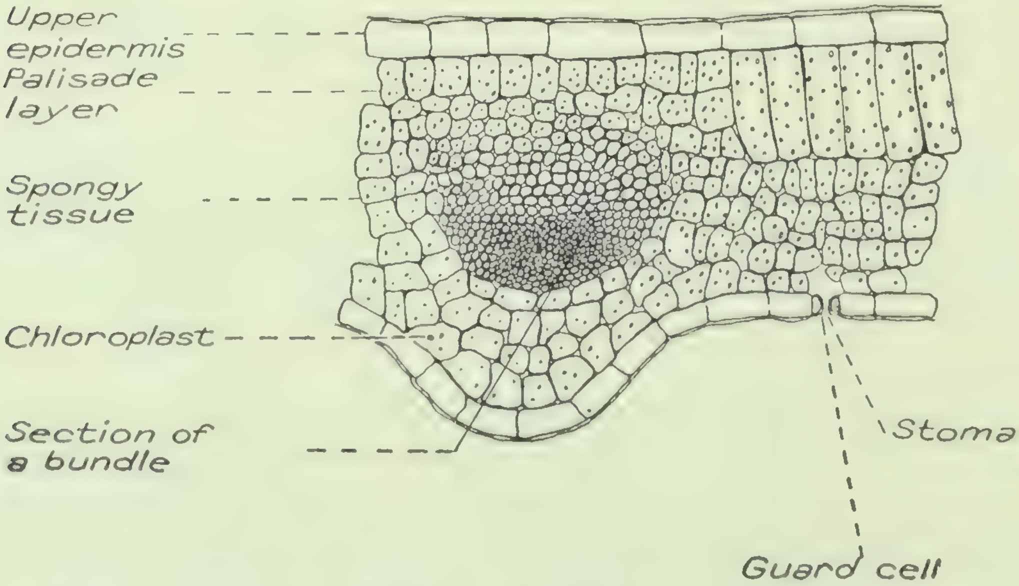


Fig. 213. What lies between the upper and lower surfaces of a geranium leaf.

Roll the blade of a leaf and cut through the folds so as to make very thin sections. If a portion of one of these sections is placed in the proper position on a microscope slide and examined under the low power, some idea will be gained of what lies between the upper and lower surfaces of a leaf.

Notice the protective skin or *epidermis* on both sides of the leaf, the compact layer of *palisade cells* under the upper epidermis, the spongy tissue with air spaces between the palisade layer and the lower epidermis, the section of a vein or bundle, and the stomata. The little specks, which are called chloroplasts, contain the green substance, *chlorophyll,* (Gk. *chloros,* green, *phullon,* leaf). This, as we shall see later, is one of the most remarkable substances in the world.

You may form an idea of the size of a leaf cell from the fact that there are eight or nine rows between the upper and lower epidermis.

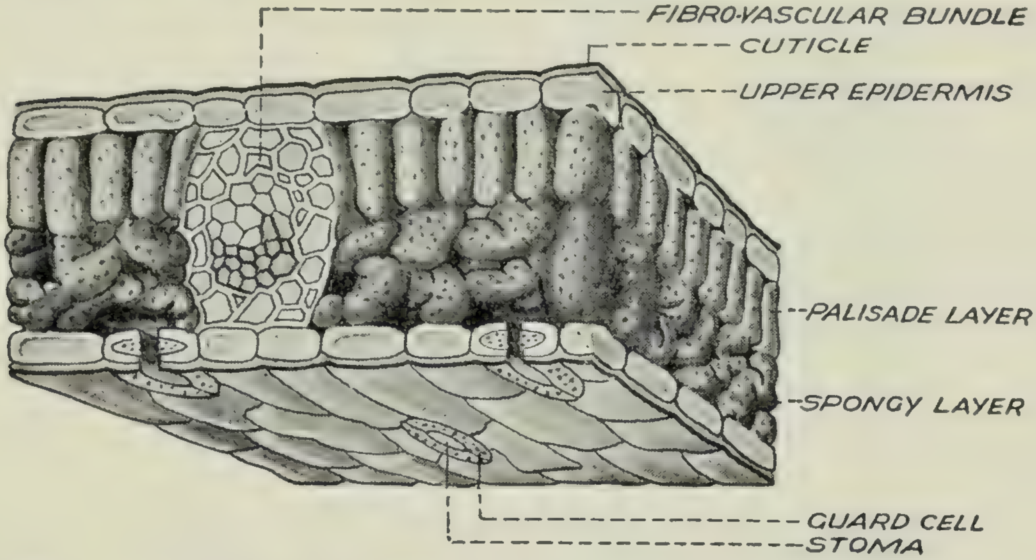


Fig. 214. Another diagram which may aid you in gaining some idea of the structure of a leaf.

The cell of spirogyra.

Examine under the low power, and then under the high, a filament of the pond plant, spirogyra. This may be found in stagnant water. Notice the series of little boxes or cells of which each strand is composed. The green colouring matter in the ribbon-like structure is chlorophyll. A colourless liquid called *protoplasm,* which resembles the white of egg, lines the cell walls and extends in strands to a denser speck of protoplasm. Between these threads of protoplasm you may observe *vacuoles* or spaces. These vacuoles are not really empty; they are filled with a dilute solution called cell sap.

When we consider how a leaf is fitted for its work we must not confine ourselves to a study of sections. It is not by chance

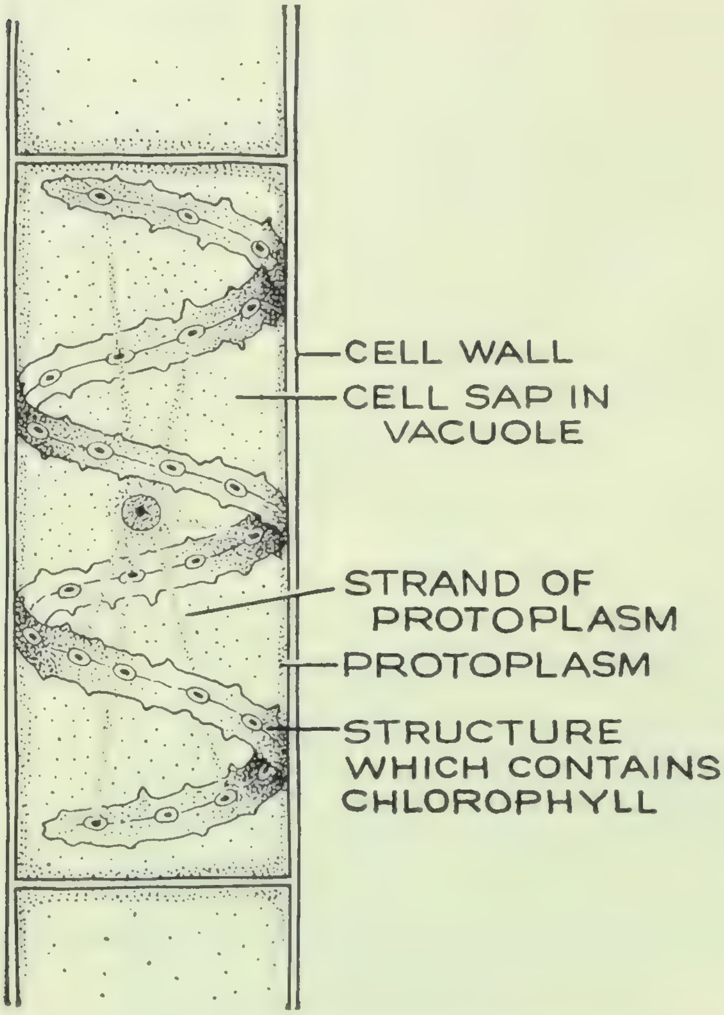


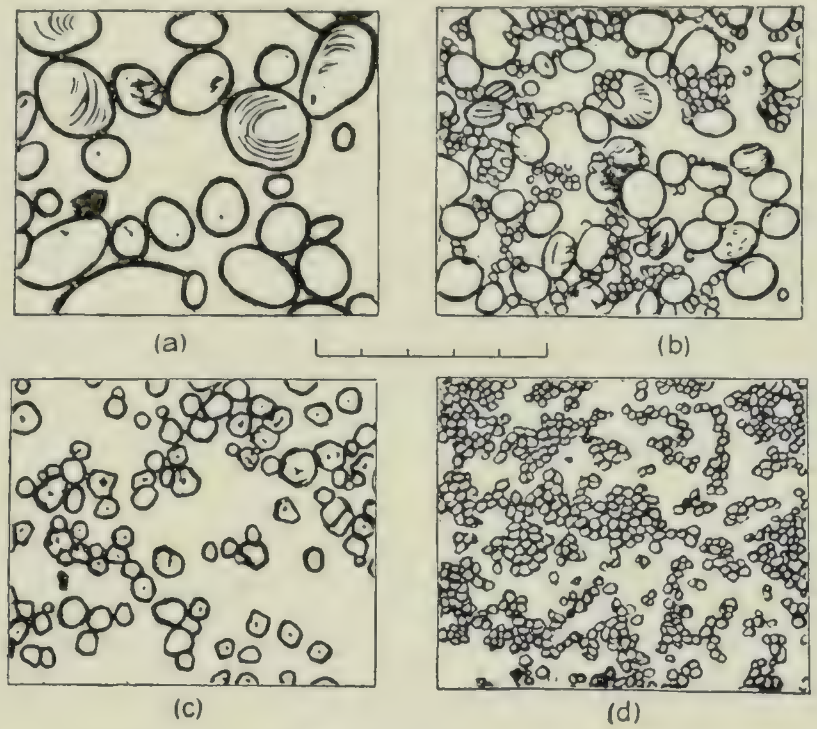
Fig. 215. A very short length of a spirogyra filament, highly magnified. The pupil should bear in mind that the cell has thickness.

that leaves of so many plants are flat, a shape that permits the exposure of a large area to sunlight; a sunflower may have about 6,000 square inches of leaf surface, a beech tree, 350 square yards and a large elm, as much as 5 acres.

The importance of starch-formation in leaves.

We know (a) that green plants die unless provided with adequate light, (b) that starch is present in leaves exposed to light and absent from those deprived of it, (c) that both plant tissue and starch contain carbon, and (d) that chlorophyll is connected in some way or other with the presence of the starch. With these facts in mind, we may pursue our study of the work of leaves in the manufacture of plant food.

The existence of carbon in starch and plant tissue gives us a valuable hint. Is it possible that leaves manufacture starch and that from this substance the plant obtains its carbon?



(From 'Forces at Work'—Andrade and Huxley, Basil Blackwell. McClelland & Stewart.)

Fig. 216. Starch grains from (a) potato, (b) oats, (c) Indian corn, (d) rice. The scale shows five one-thousandths of an inch.

Botanists have discovered that the chlorophyll in leaves, using energy from sunlight, manufactures starch and that this starch provides the plant with its carbon.

PROBLEM IV: Where is the carbon in the starch obtained?

It is astounding to think of the quantities of vegetation grown annually; the grain alone of one Canadian crop, wheat, amounts to some twelve million tons. We know that much of the weight of plants consists of water; when they are so thoroughly dried that all the water is removed, nearly half of the remainder is carbon.

What is the source of the carbon, millions of tons of which enter annually into the new growth of plants? It cannot come from the soil, for plants will thrive in solutions from which carbon is absent. There is the possibility that carbon is obtained from the air. At first, this seems a rather absurd suggestion for there are only four cubic feet of carbon dioxide in every ten thousand of air and, in addition, gases are very light substances. Yet, it is estimated that human beings alone release 50,000,000 tons of carbon dioxide into the air each year. Then there are the enormous amounts produced by animals in their respiration, and the huge quantities set free in the burning of coal, wood, and oil. Tons of the gas enter the air daily from the exhaust pipes of automobiles. When we are told the atmosphere contains roughly 2¾ million million tons of carbon dioxide it does not seem so unreasonable to suggest that this is the huge reservoir on which plants draw for their needs.

Plants containing chlorophyll take carbon dioxide from the air through their stomata, and from this gas and water obtained from the soil starch is constructed. From the starch and small quantities of nitrogen, phosphorus, iron, sulphur and other substances derived from soil-water, the green plant is built up.

There is another matter which remains for consideration.

Green plants in the presence of sunlight release a gas.

(i) No pupil who has watched an aquarium can have failed to notice at times a stream of bubbles coming from the leaves of the water plants.

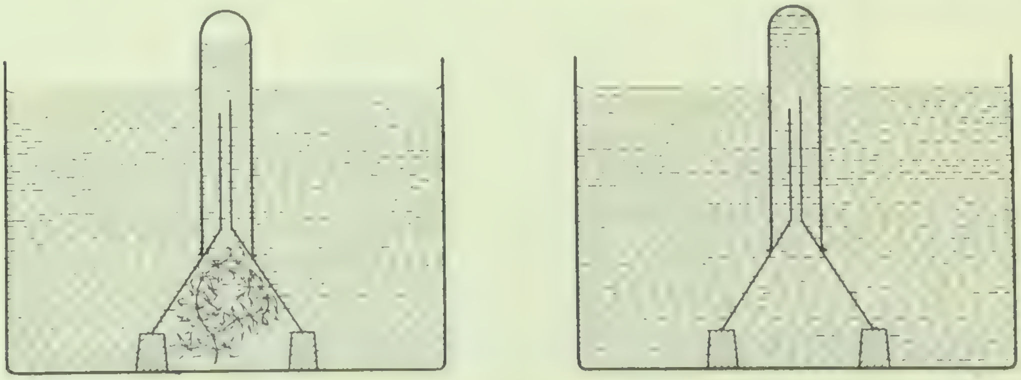


Fig. 217. Green plants in presence of sunlight release a gas.

If a test-tube filled with water be supported in the inverted position over the stream, the gas can be collected. When a quantity of the gas has been obtained, insert into it a glowing splint. What happens when a lighted match is held in a jar of carbon dioxide?

Are bubbles liberated as freely when the aquarium is in sunshine as when it is in shade?

(ii) Pour about equal quantities of water into two dishes, (Fig. 217). Leave them for a few hours until the water attains the temperature of the room. Pass carbon dioxide through the water in each container. Then, in one place a piece of Canada waterweed, water cress, or some available water-weed, and over it set a funnel and test-tube. The latter should be filled with water taken from the dish.

If gas should collect in the test-tube, we would be uncertain about its origin. It might have come from the water, it might have come from the plants, or both might have been sources. To remove this uncertainty, it is necessary to set up an apparatus similar in every respect except one—the plant should be absent. For this purpose we use the water in the second dish. The two pieces of apparatus should be set side by side in a place where they will receive direct sunlight for part of the day.

Examine the test-tube from day to day. Does gas collect in the test-tube of the control apparatus? If it does, account for its presence. Has the waterweed given off a gas? If it has, test the gas with a glowing splint and decide whether or not it is carbon dioxide.

Why have we used a water plant in this experiment?

Now we are in a position to sum up our knowledge of the process of food construction in green leaves.

(1) When the green plant is exposed to light, carbon dioxide from the air enters the leaf through the little pores or stomata.

(2) In the leaf, the carbon dioxide comes into contact with water which the roots of the plant have obtained from the soil.

(3) The chlorophyll, using the energy of sunlight, constructs food substances, one of which is starch.

There are good reasons for believing that grape sugar is manufactured from carbon dioxide and water prior to the starch. It is estimated that a leaf the size of this page can make about half an ounce of sugar in a month. The sugar dissolves in water and a certain amount is carried away through the transportation system of the plant. However, so rapidly is the sugar manufactured that the sap is unable to take all of it away. If the sap became heavily charged with sugar, its motion would be impeded. This is avoided by the conversion of much of the sugar into starch, which is insoluble in the sap. At night, manufacturing ceases, and the starch formed during the day is changed back to sugar. This is removed by the transportation system, leaving the factory ready for work again in the morning.

Often it happens that the sugar after being carried away from the leaf is changed back once more into starch and stored as such, for instance, in the potato tuber.

(4) In most manufacturing operations there is some waste product. It is interesting to know that the refuse in this wonderful process is the gas oxygen which escapes through the stomata into the air.

Comparison of leaf and factory.

The green pigment, chlorophyll, may be thought of as a machine by which the raw materials, carbon dioxide and water, are converted into food for the plant.

Unless a factory is supplied with energy derived from sources such as falling water, fuel, or electricity, the wheels do not turn. Similarly, the chlorophyll is unable to manufacture food unless light is present. Indeed, unless there is light, the chlorophyll is not even formed. When potato tubers sprout in a dark cellar, the stalks are white; not until some light reaches them does green appear.

We may complete our comparison of the factory and leaf as follows:

Machine	Chlorophyll
Energy	Sunlight
Working hours	Daytime
Raw materials	Carbon dioxide and water
Manufactured articles	Sugar and starch
Waste (or by-product)	Oxygen

The manufacture of food by plants in sunlight is called *photosynthesis*. (Gk. *phos*, light; *synthesis*, building up.)

Exercises:

1. Make a list of the substances which plants must obtain in order to live.

2. Would you include sunlight among the green plant's necessities of life? If you would, explain why. Is soil one of the necessities? Explain.

ENRICHMENT SECTION, NUMBER 13.

Some plants like very little light.

Some plants thrive and flower only when the supply of light is relatively small. Among these "short day" flowers are chrysanthemums, cosmos, nicotiana, dahlias, and asters.

Too much sunlight causes sugar to be changed into cellulose in certain plants. Rhubarb is "stringy", celery fibrous, and asparagus tough, unless they have some shade.

Many other changes occur; changes in the amount of foliage, the size of flowers, the length of stems, the number of seeds, as plants adjust themselves to the amount of light they receive.

Exercises:

1. List as many adaptations as you can of plants seeking to fit themselves to conditions of light.
2. Where do we find wood violets, moss, or ferns growing? Why?
3. What is meant when we speak of "bleaching" celery?

D. MINOR STUDY: The respiration of plants.

Every time we breathe, some of the oxygen of the air is used up and its place is taken by carbon dioxide. Do plants respire like human beings and animals? Do they also take in oxygen and release carbon dioxide?

Release of carbon dioxide by plants.

(i) Put some water into a bottle with a narrow neck. Place as many fresh geranium leaves as possible in the bottle so that their stalks dip into the water. Set the bottle on a piece of board the area of which is a little greater than that of the mouth of a bell-jar, and place beside the bottle a dish of lime-water. Cover the two vessels with a bell-jar and by means of vaseline make the apparatus air-tight. (Fig. 219). Set up a control apparatus in which the leaves are omitted. Leave both bell-jars and their contents in a dark cupboard for several days. Is there any indication that the leaves have given off carbon dioxide?

(ii) A similar experiment, in which germinating seeds replace the leaves, may be performed.

Living plants take in oxygen and release carbon dioxide, just as animals do. This operation is not performed in darkness only, but takes place also in daytime. However, we have learned that in sunlight the reverse also occurs, carbon dioxide is used by the plant, oxygen is set free.

Process	Time	Gas used	Gas set free
Photosynthesis	In sunlight	Carbon dioxide	Oxygen
Respiration	Day and night	Oxygen	Carbon dioxide

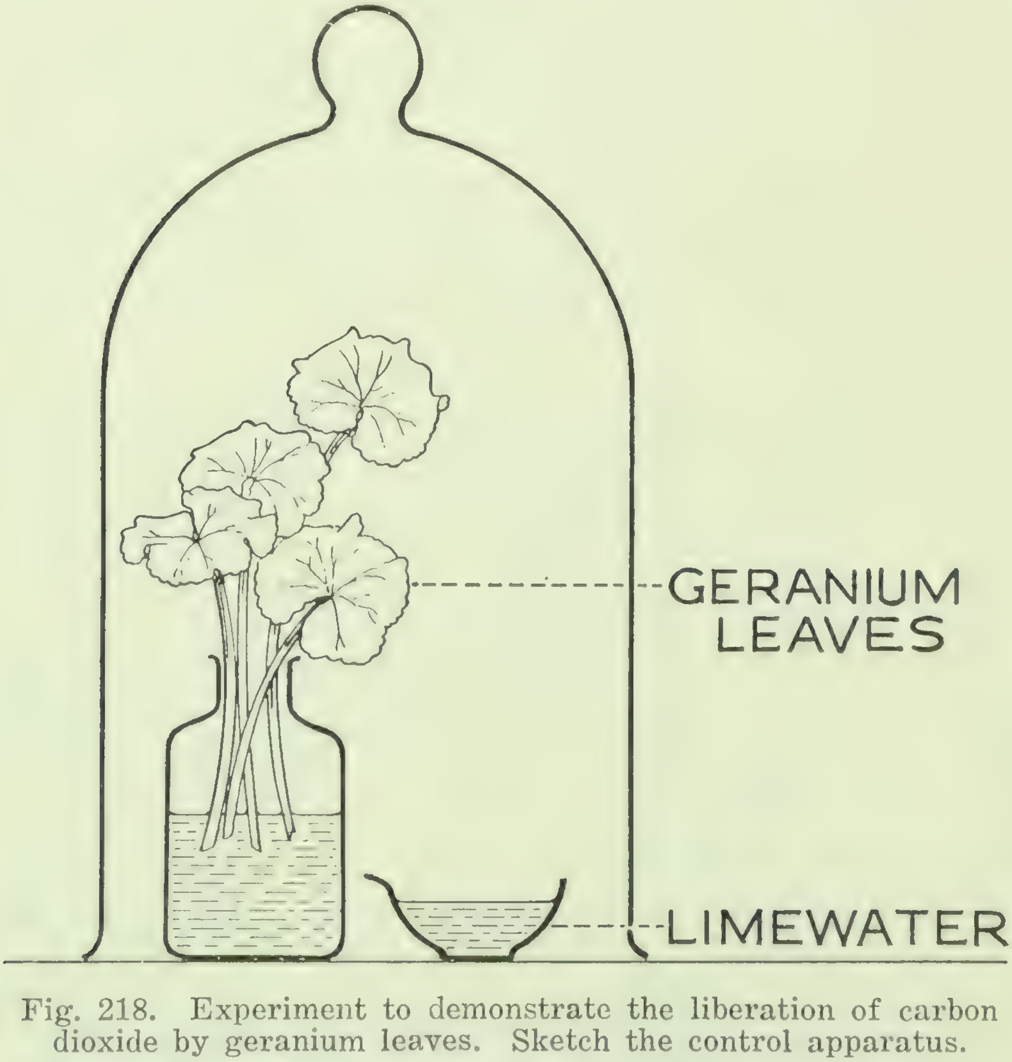
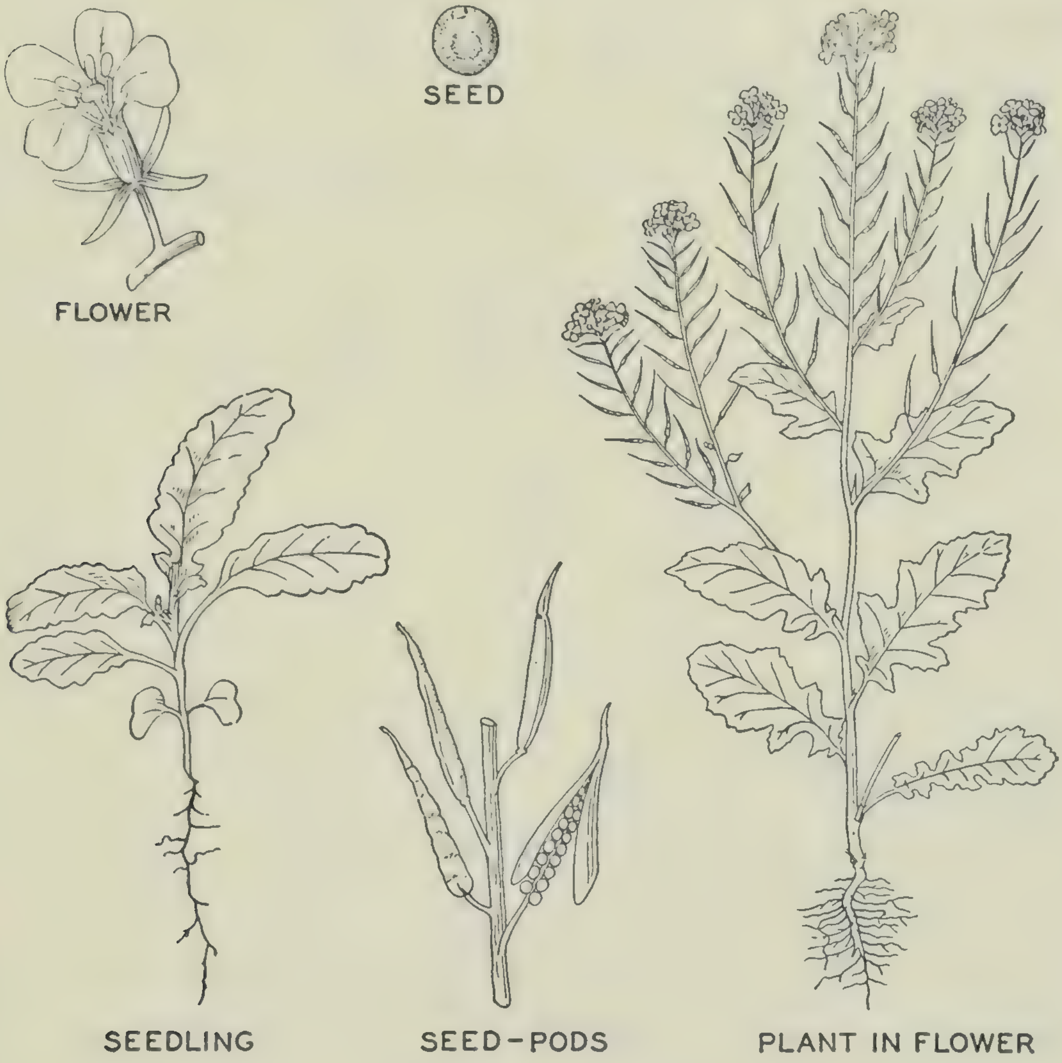


Fig. 218. Experiment to demonstrate the liberation of carbon dioxide by geranium leaves. Sketch the control apparatus.

In sunlight, the effect of respiration is obscured by that of photosynthesis. Since plants accumulate large quantities of carbon, it is obvious that during their lifetime they use up more carbon dioxide than they set free, and liberate more oxygen than they take in.

E. MINOR STUDY: How flowering plants provide for the continuance of their kind.

It is not enough that plants should be able to live. They must also provide for the continuance of their kind. Although there are means of reproduction other than by means of seeds, we shall first make some observations on the latter method.



219. Wild mustard.

(Redrawn from "Weeds" by W. C. Muenscher; courtesy of the Macmillan Co., New York.)

Examination of the seeds of wild mustard.

With the aid of a magnifying glass, examine a ripened seed of wild mustard. Describe the seed. To the seed of what other plants does it bear resemblance? Estimate the number of seeds that may be borne by a fully-developed mustard plant. Suggest an advantage to the plant arising from the fact that all the pods are not ripened at the same time. Mustard seeds have remarkable vitality. They may lie buried in the soil as long as fifty years before giving rise to new plants. How is this property of advantage to the mustard? What difficulty does it make for the farmer?

Now we shall study the development of a new plant from a seed.

PROBLEM I: What changes may be detected by the naked eye when a bean seed germinates?

(i) At a depth of about an inch, plant some broad and kidney beans in separate flower pots. For the sake of comparison, a bean of each kind should be planted every day until the pot contains a sufficient number. Observe the development of seedlings and, by means of a series of drawings, show the changes that occur.

When the first seedlings appear above the surface of the soil, allow some seeds to germinate (Lat. *germen*, bud).

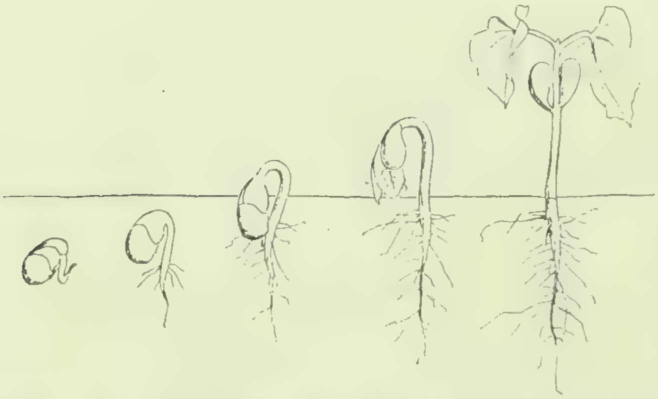


Fig. 220. Development of a bean seedling.

(ii) Soak some bean seeds in water for two or three hours. Inside a glass vessel place a piece of blotting-paper so rolled that it fits tightly against the sides of the container. Place the seeds between the paper and the sides and then fill the vessel with sawdust. Keep the latter moist.

Compare dry bean seeds with those that have been soaked. What changes have occurred? Squeeze a number of well-soaked beans. From what part does water emerge?

What part of the seedling appears first? Of what advantage, if any, is it to the young plant that, in the beginning, this part should grow more rapidly than others?

From what part of the seed does the root emerge? In what direction does it grow? Examine the root with the aid of a lens and describe it.

Tell how the seedling makes its way upward through the soil. Is the part from which the first little leaves develop pushed up or pulled out of the soil?

Does the larger portion of the original seed leave the soil or remain in it? (Examine seedlings of both broad and kidney beans.) If it leaves the soil, describe any change that takes place in it and observe what becomes of it eventually.

We have observed the development of a bean seedling. Now we shall examine a seed in order to learn something of its structure, and especially to find if the little plant is present before germination begins.

PROBLEM II: Of what does a bean seed consist?

Soak some bean seeds of different kinds for three or four hours. Observe the exterior both of these and unsoaked seeds. Try to discover the *scar* left when the bean was detached from the pod. Close to the scar look for a little opening. It was at this pore that water appeared when a well-soaked bean was squeezed. Much of the water that entered the seed passed through this opening.

Remove the skin or *seed-coat* from a soaked bean. Is this operation easily performed on one which has not been placed in water? Separate the two parts of which the seed is seen to be composed after removal of the seed-coat

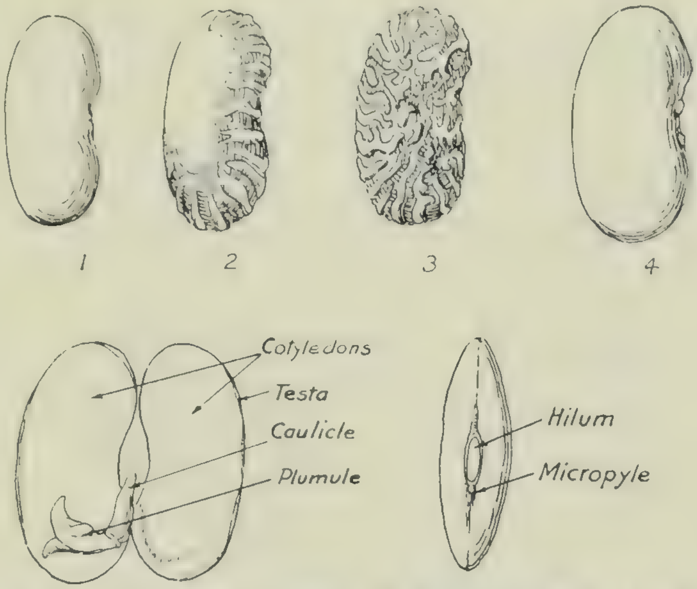


Fig. 221. Four views of a bean seed as it absorbs water. At first the seed-coat wrinkles, but later the starchy matter gradually becomes soluble and swells to fill out the seed-coat again until it ruptures to allow the caulicle and plumule to emerge.

Previously you noticed that these two large divisions of the seed were raised into the air by the kidney bean seedling, that they became green in colour, and, after a time, withered away. They are known as *seed-leaves* or cotyledons. Their size is due to the presence of a store of food which is used by the little plant until it is thoroughly established. On this account they are sometimes called 'nursing leaves'. Compare this provision of food for the seedling with the nourishment supplied by animals for their young. Almost all of a hen's egg consists of food for the developing chick.

In many plants, including, as you have noticed, some beans, the seed-leaves remain in the soil.

With the aid of a lens, examine the little structure lying between the seed-leaves. From it develop the root, stem and leaves of the seedling.

At one end of it may be seen the bud from which the first true leaves of the plant develop. Because of its appearance, this bud is called the *plumule*, (Lat. *plumula*, a little feather).

Hence, a bean seed consists of a seed-coat and an embryo plant provided with two 'nursing leaves'.

Notice the curvature of the part between the seed-leaves. Recall the arch formed when the seedling first appeared above the ground. What is the connection between the two? Now we can see a reason for this method of emergence from the soil. Since it was *pulled* rather than pushed through the soil, the delicate upper part of the little plant escaped injury.

PROBLEM III: What is the effect of removing a seed-leaf?

Cut off one seed-leaf of a bean seedling. Compare the growth of this plant with that of others from which the seed-leaves have not been removed.

PROBLEM IV: From what structures do seeds develop?

Before turning our attention to the seeds let us discover the origins of the *pods* of the wild mustard and the bean.

It is a matter of common observation that these pods are

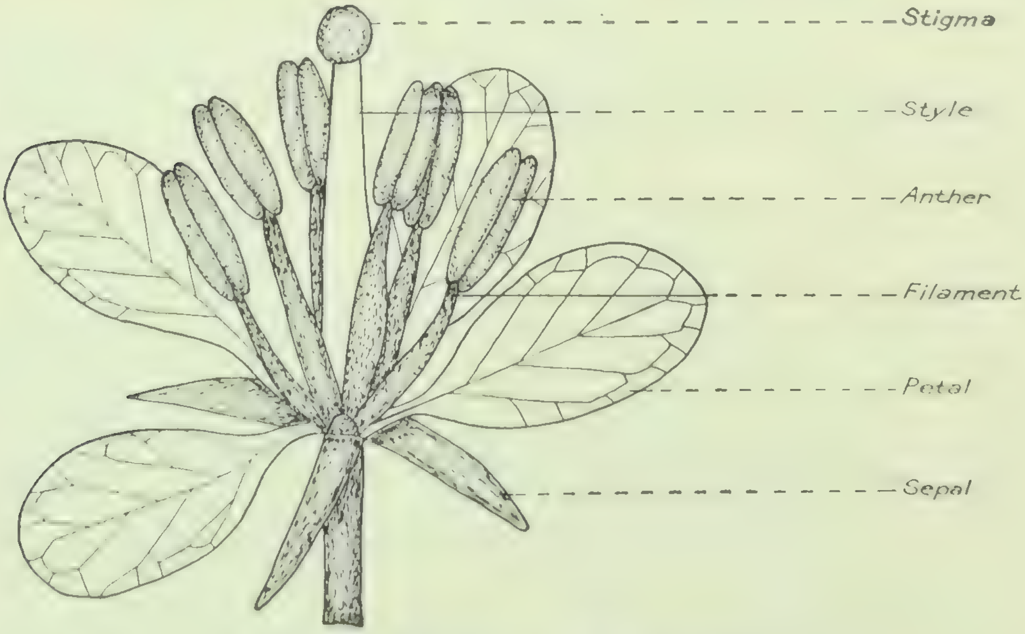


Fig. 222. Flower of wild mustard.

found in places formerly occupied by flowers. Accordingly, some observations on the flowers may prove useful to us.

Observations on the flower of wild mustard.

Find some 'old' mustard flowers, that is to say, flowers from which the yellow *petals* have fallen. Find a structure which looks like an immature pod.

Now examine some flowers which still retain their petals. Locate the same structure in these blossoms and examine it with a hand lens. It is called a *pistil*. At the upper end is the rounded *stigma*. Just under the stigma is a short stalk, the *style*. Below the style is a relatively long swollen portion, the *ovary*. (See Fig. 222.)

Cut across a pistil and also a pod. Examine the sections with a magnifying glass. Are there any features common to both?

From what part of the mustard flower does a pod develop?

Now we shall examine the flower and pod of a bean plant. (For this plant may be substituted the pea or caragana.)

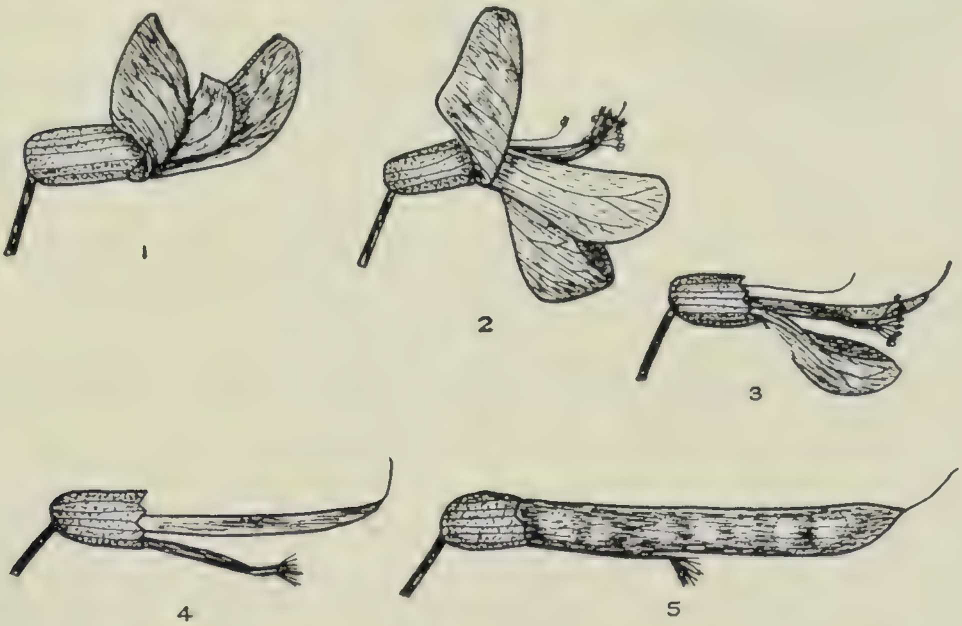


Fig. 223. Stages in the development in the pod of caragana.

Origin of the bean pod.

To understand the development of the pod of the bean, pea, or caragana, it is necessary to examine the pistil in a newly-opened flower, the little pod in a flower from which the petals have fallen, and a mature pod.

Make two sections of the ovary, one transverse, the other, longitudinal. Examine the longitudinal section, and, with the aid of a lens, find little bodies which occupy positions corresponding to those of beans in a pod. Each of these small objects is called an *ovule*, a word which means literally 'little egg'.

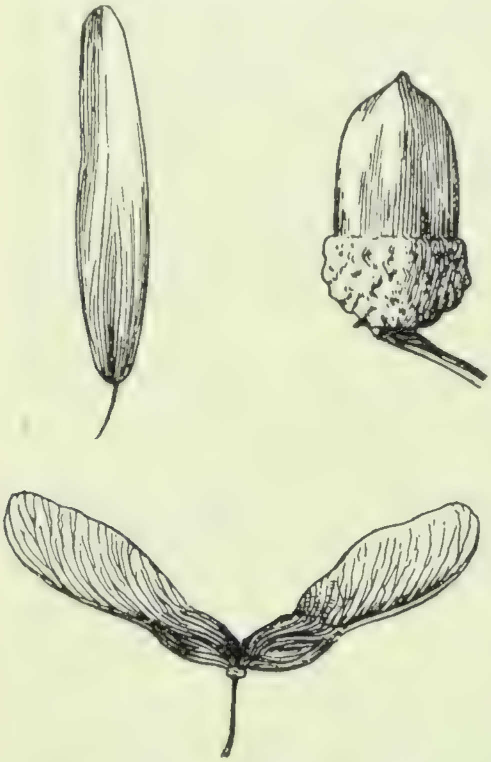


Fig. 224. Three fruits.

Upper left figure: Key of ash.
Upper right figure: Acorn.
Lower figure: Double key of maple.

In an immature pod, notice the seeds. Find also the style of the original pistil. Is there any other structure attached to the pod which formerly was part of the flower? From what parts in the original pistil have the seeds developed? What was the origin of the walls of the pod?

The average person is accustomed to think of a fruit as something which is luscious, fragrant and attractively coloured. Botanists do not restrict themselves thus. Not only do they include the apple and strawberry among fruits, but also tomatoes, maple keys, oat grains, corn kernels, burs of burdock, the pea or bean pod with its enclosed seeds, and the mustard pod with its seeds.

These fruits developed from parts of the original flower; the seeds in the fruits were derived from ovules.

However, before the development of a fruit can take place, before an ovule can undergo those changes which result in a seed, a very important process must take place.

PROBLEM V: What is it that starts the changes that lead to the ripened seed?

Before an answer can be given to this question, it is necessary for us to learn a little more about the parts of a flower.

Fig. 225.

Mass of buttercup fruits after the petals have fallen.

Further examination of a wild mustard flower.

From a mustard flower remove two petals and also two of the little green structures found below them. (These small green leaves are called *sepals.*) See Fig. 222.

Notice a number of little stalks surrounding the pistil. Each is called a *stamen.* How many stamens are there in the mustard flower? The stalk itself is called a *filament.* At the upper end of each filament is a structure known as the anther.

From the anthers comes the pollen, a powdery substance, which, as we shall see, is of the utmost importance to the plant. Pollen is easily seen in large flowers like the lilies. Probably you have powdered your nose with it at one time or another when smelling a flower.

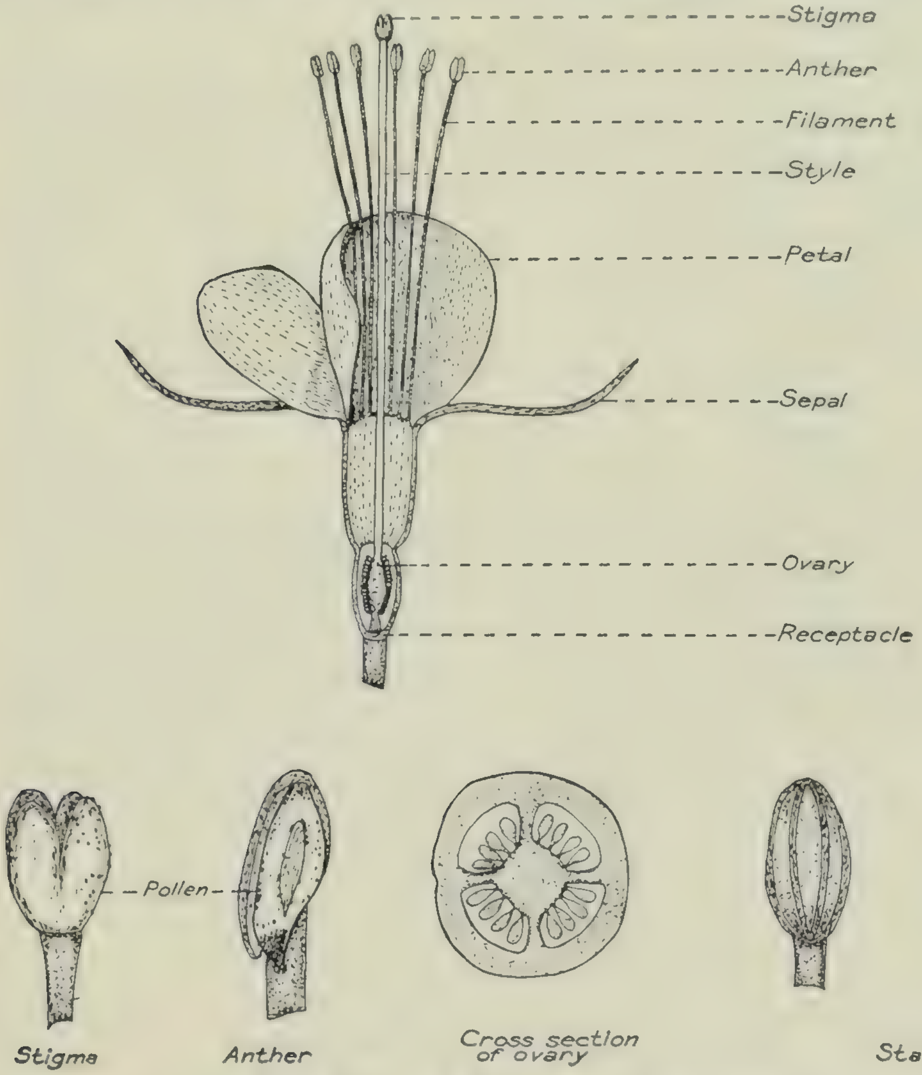
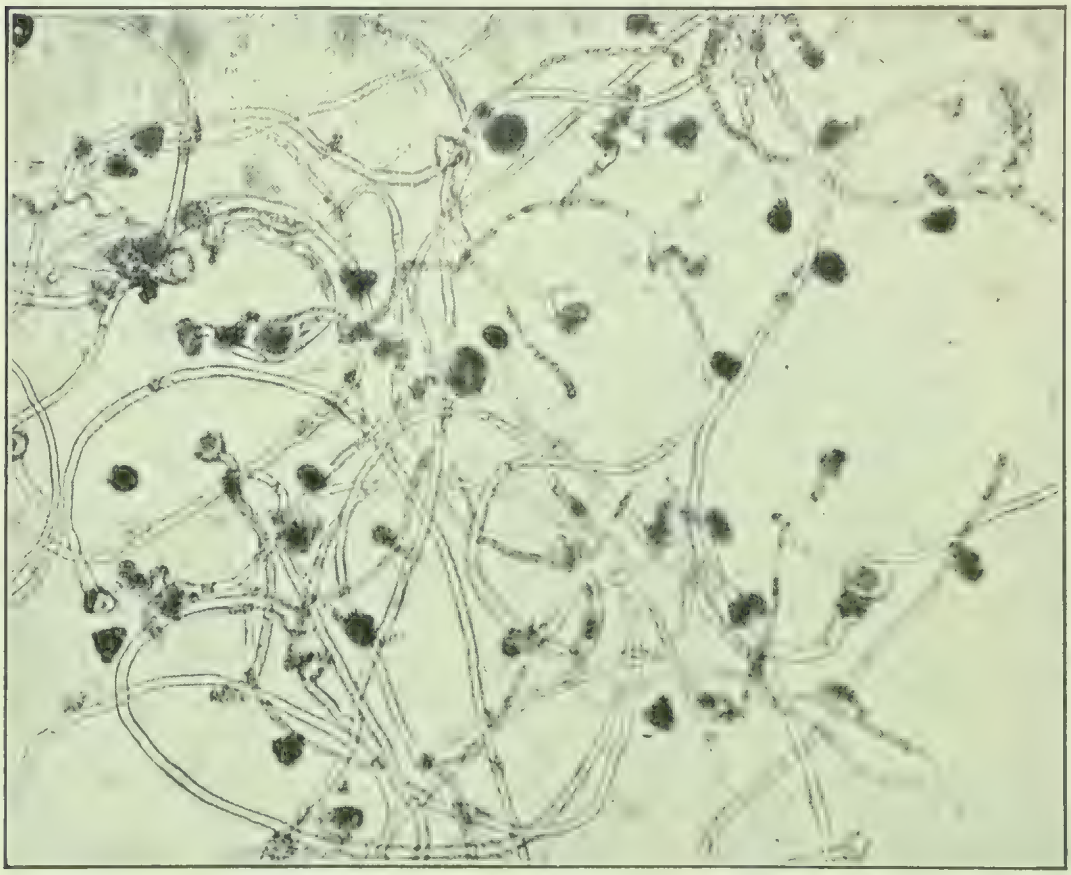


Fig. 226. A flower and its parts.

An ovary of a flower contains one or more ovules, the number depending upon the kind of plant. When a grain of pollen falls on the stigma of a mature pistil, it sends out a tube which passes down a tiny canal in the style, and finally reaches one of the ovules in the ovary. Then the ovule and part of the contents of the tube unite. As a result of this union, which is called *fertilization*, a seed begins to form. Should an ovule not be fertilized, a seed will not develop.

One cannot reflect on the process without a feeling of wonder. Frequently, the first obvious result of the fertilization of the ovules is the fading and falling of the petals. It would seem as if fertilization had caused death. This is far from the truth, for before the petals withered new life had begun in the ovary.



(Courtesy of the Missouri College of Agriculture.)

Fig. 227. Tubes of apple pollen.

Find in a bean seed a little opening close to the scar. Through this pore, known as the micropyle, a pollen tube entered to fertilize the ovule. (See Fig. 221.)

PROBLEM VI: **From which stamens does the stigma receive pollen?**

One may inquire if the stigma received pollen from stamens on the same plant or from stamens on other plants. In other words, is there self-pollination or cross-pollination? This depends upon the kind of plant. For example, tobacco, wheat, barley, oats, and the garden pea are self-pollinated. Most flowering plants are cross-pollinated: the pollen is obtained from a flower on a different plant of the same or a closely-related kind.

Many plants for which cross-pollination is the "preferred" plan fall back on self-pollination in emergency. In wild mustard, for instance, the pistil gradually becomes longer as the flower becomes older so that the stigma is pushed past the anthers. Thus, if cross-pollination has not been effected already, self-pollination will be brought about, provided, of course, that some pollen still remains.

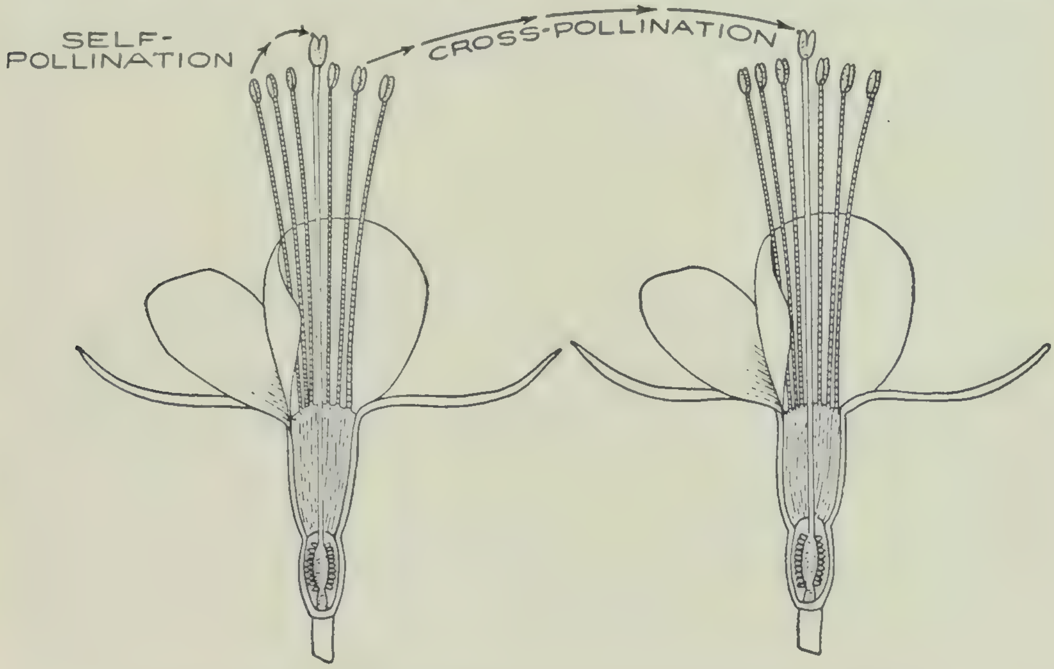
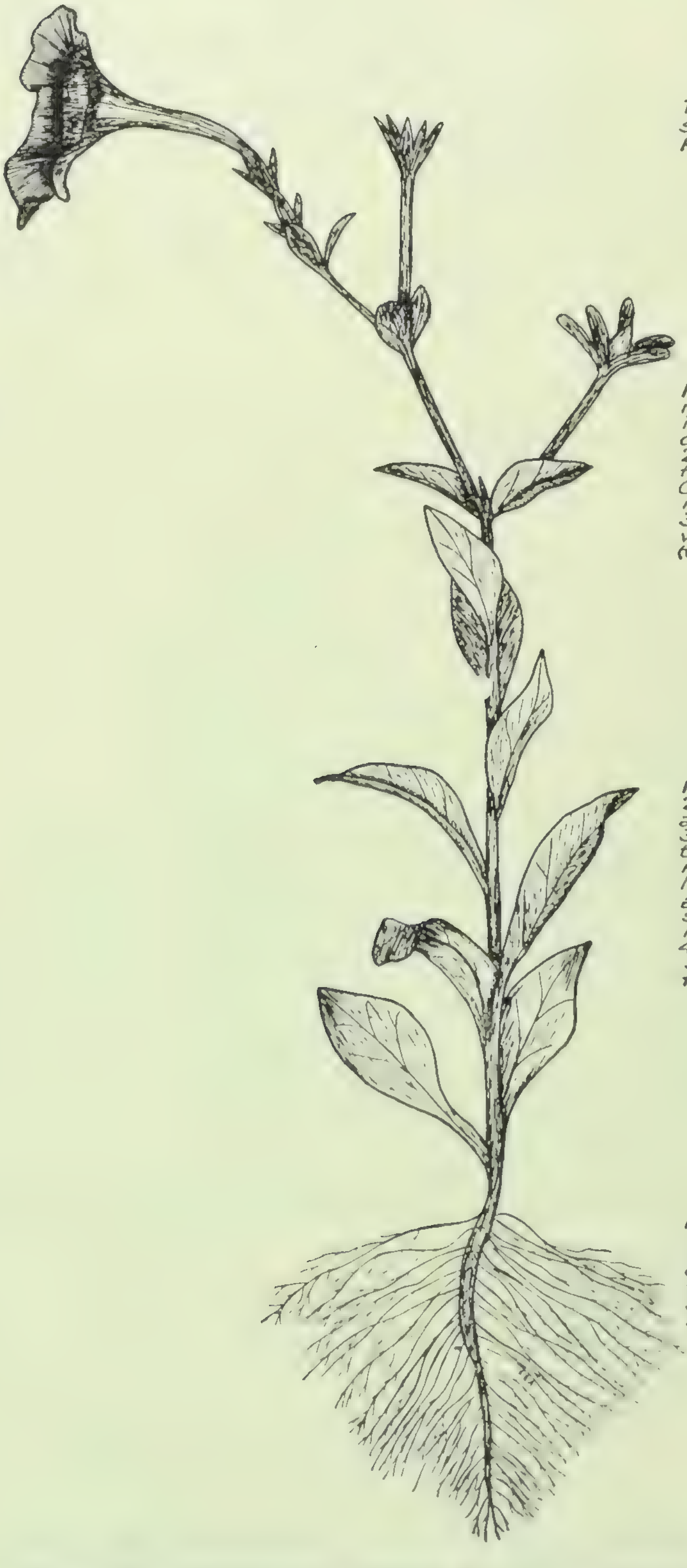


Fig. 228. Self-pollination and cross-pollination.

There are some flowering plants such as white and red clover in which no seed is formed unless cross-pollination takes place. Although self-pollinated plants like wheat do not seem to suffer, it is generally agreed that those which may be either cross or self-pollinated produce more vigorous seedlings when cross-pollination is effected.



FLOWER

The flower develops seeds which may produce new plants.

LEAF

1. Leaves carry on respiration. Oxygen is taken in, carbon dioxide is released.
2 They manufacture food (photosynthesis). Carbon dioxide is taken in, oxygen is set free.
3. They release water vapour into the air (transpiration).

STEM

1. Stems respire
2. If a stem is green it assists in photosynthesis.
3. The stem contains tubes through which food manufactured in the leaves passes downward and solutions of mineral salts absorbed by the roots move upward.
4. In some plants the stem acts as an organ for food storage.

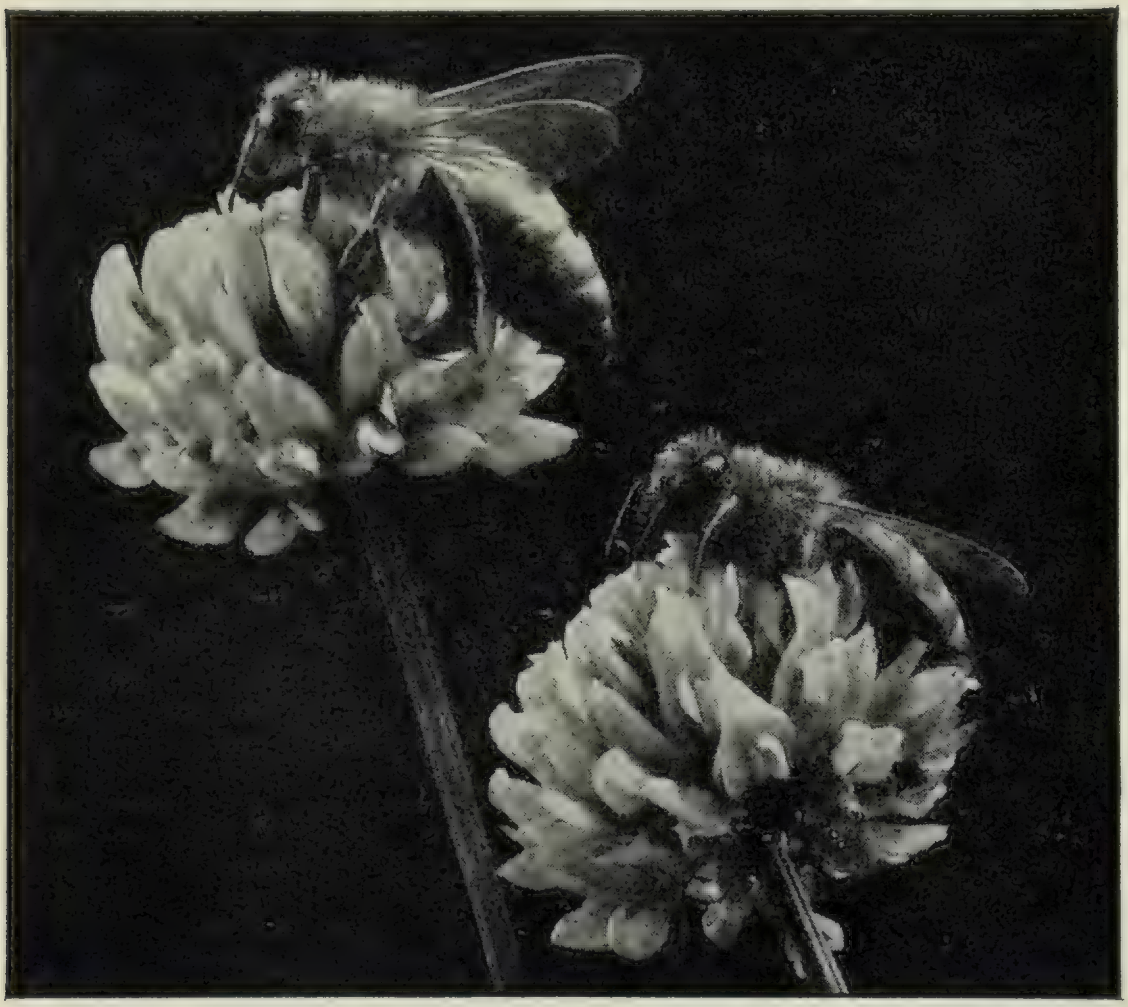
ROOT

1 The root holds the plant in position.
2. It absorbs solutions of mineral salts from the soil.
3. In some plants the root acts as a storage organ.

Fig. 229. Summary of the functions of the parts of a plant.

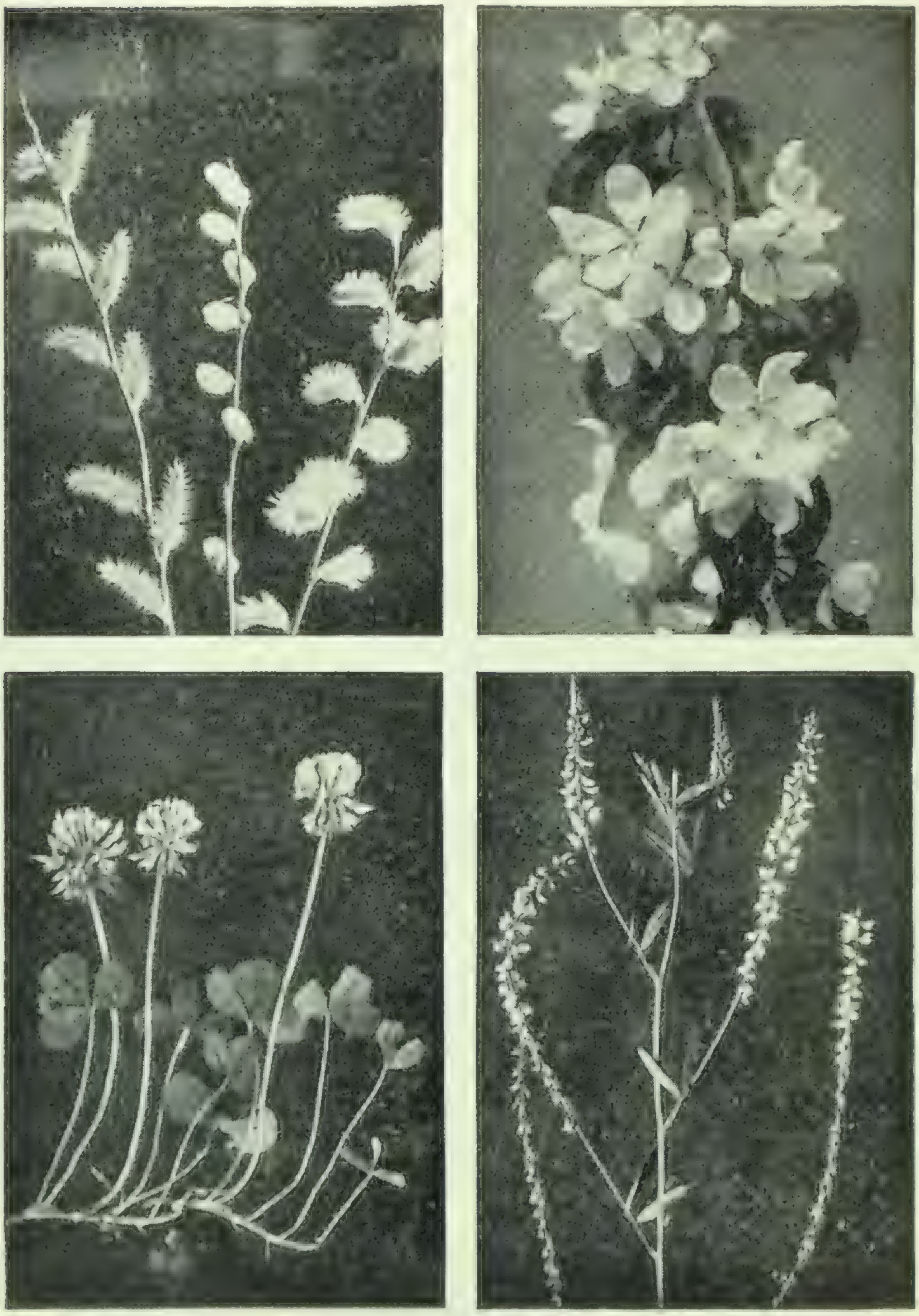
PROBLEM VII: How is cross-pollination brought about?

(a) *Cross-pollination by insects.* Even the most unobservant person can hardly fail to notice how insects are attracted to flowers. There is something almost comical about that model of industry, the bee, as it bustles from blossom to blossom. These treasure-seekers are in search of the nutritious pollen and the sugar solution, nectar. In wild mustard, the nectar collects at the bases of the stamens. The benefits to the insect of this floral diet are obvious enough, but what does the plant receive in exchange for its stolen pollen and for the nectar which seems to be provided solely to attract visitors?



(By kind permission of Edith Patch and the Macmillan Co. of New York, from "Surprises" by Patch & Howe.)

Fig. 230. Bees attracted by the nectar in clover are the agents by which cross-pollination is effected.



(*Courtesy of the Dominion Dept. Agr.*)

Fig. 231. Four important nectar-yielding plants.

Top left—Pussy willow. Top right—Apple blossom.
Bottom left—White Dutch clover. Bottom right—Sweet clover.

Why should so many plants which possess these desirable food commodities have odours or showy colours?

When an insect explores a flower, some of the pollen grains, which in many plants have rough coats, cling to its body. These grains are carried to the stigma of another flower and thus cross-pollination is effected. This is the return which the plant obtains for the nectar and excess pollen it produces.

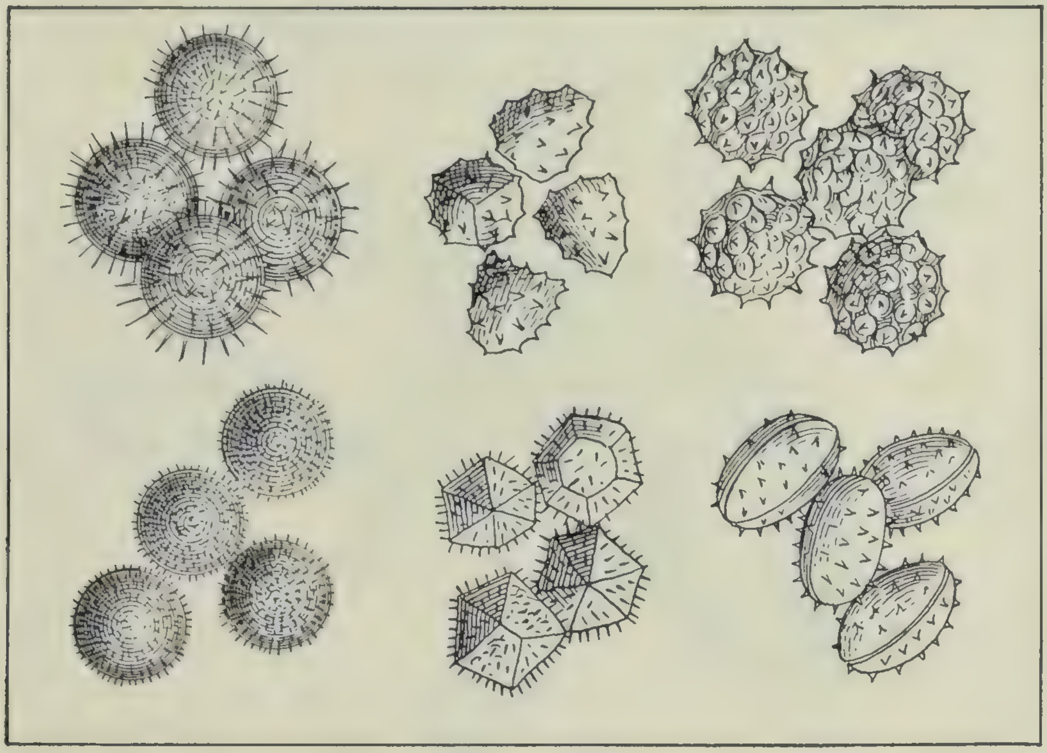
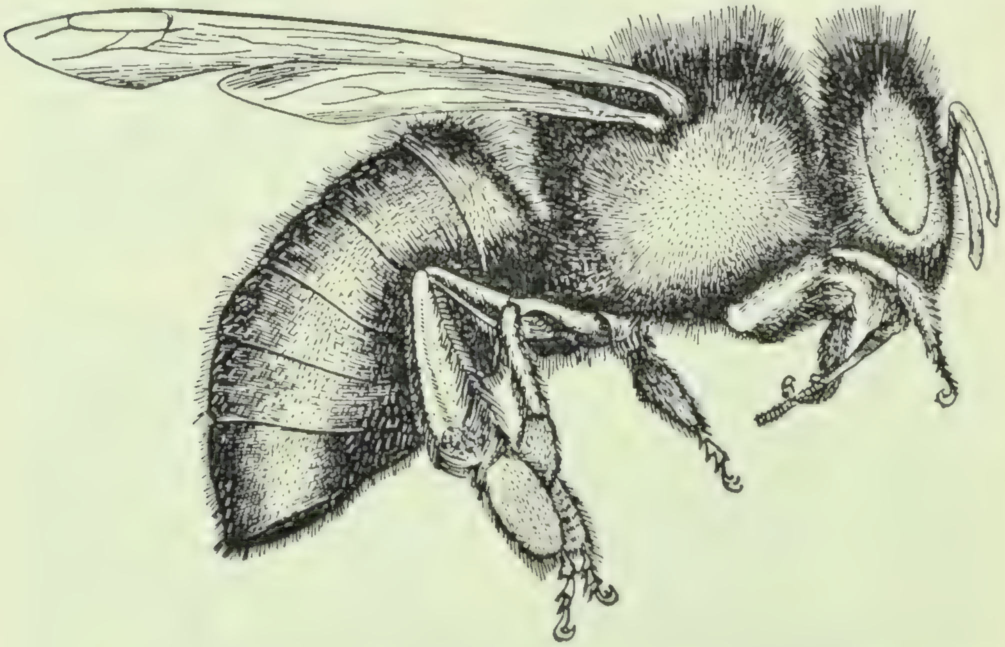


Fig. 232. Pollen grains, highly magnified. If a fairy wanted a one-inch necklace of dandelion pollen, she would have to string together a thousand grains.

These are the rewards for which the insects unwittingly perform an important service to the plant. The colours and odours are advertising tricks to attract the attention of the insects. Even when the odours are unpleasant to us—that of the red trillium reminds some people of tainted meat—they are effective. It is said that if bees became extinct hundreds of kinds of plants would vanish quickly off the earth. In order that seed might be obtained from red clover introduced to New Zealand, it was necessary to send to Great Britain for bumble-bees.

We have mentioned that plants advertise. This is not the only business device to which they resort. Many of them have solved the problem of increasing the efficiency of their advertising without incurring undue expense. This is done by massing the bloom, as in mustard and toadflax. In composite flowers, such as dandelion, chicory and sow thistle, many flowers, so small that separately they would be unseen, are grouped in heads.

(b) *Cross-pollination by wind.* Many kinds of plants take advantage of that natural transporting agent, the wind, to secure cross-pollination. The wind needs no reward for its work and advertising would be wasted on it. Consequently, we find in wind-pollinated flowers no nectar, no odour and no bright colours. However, there are greater risks involved in this method, for "the wind bloweth where it listeth." To make allowance for the greater uncertainty of wind-pollination—as compared with insect-pollination, vast quantities of pollen are produced. As a rule, the pollen grains of wind-pollinated plants are smaller than those of plants pollinated



(Redrawn from Bull. 121 by permission of U.S. Dept. of Agr.)

Fig. 233. This flying bee is removing pollen from its face and mouthparts.

by means of insects. Pollen grains of pine, another wind-pollinated plant, are provided with tiny air-sacs which give them buoyancy. Many plants depending upon wind have feathery stigmas, thus exposing a larger surface.

Most grasses, sedges, and trees are wind-pollinated.

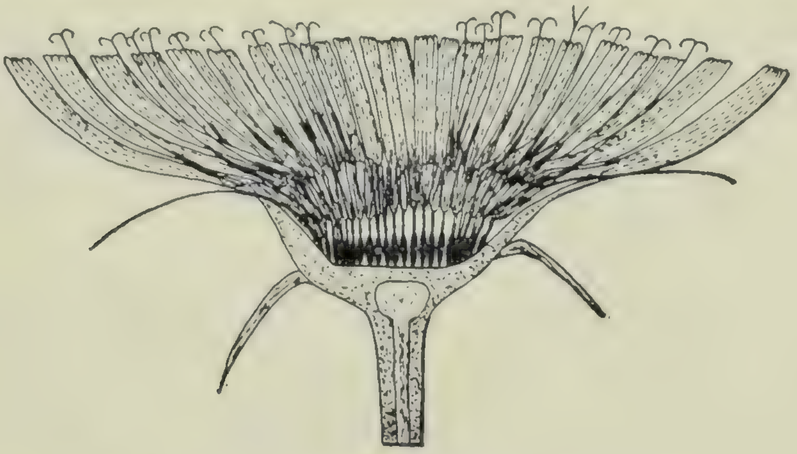


Fig. 234. Section of dandelion head.

It is of some interest to learn that pollen is sometimes carried by birds, snails, and in the case of certain aquatic plants, by water.

PROBLEM VIII: How are fruits and seeds scattered?

One must be impressed with the very great numbers of seeds produced by most flowering plants. If all of these were to fall near the plant which produced them, the competition among the seedlings for sunlight and moisture would be very keen and few, if any, would survive. This struggle would be increased if the parent plant were perennial.

By means of its seed, a plant continues its kind and there is obviously a greater chance of success if they are scattered over a wide area. Many seedlings die but since "all the eggs are not in one basket" there is an increased likelihood that some of the young plants will come to maturity.

What are the means, other than purposeful sowing by man, by which seeds are scattered or dispersed?

(a) *Dispersal by wind.* We may observe in a number of fruits, such as those of the elm, ash and maple, the possession of a wing-like growth. The seed itself may have such an outgrowth, as in the case of the toadflax. These expansions make easier the scattering of the fruit or seed by wind.

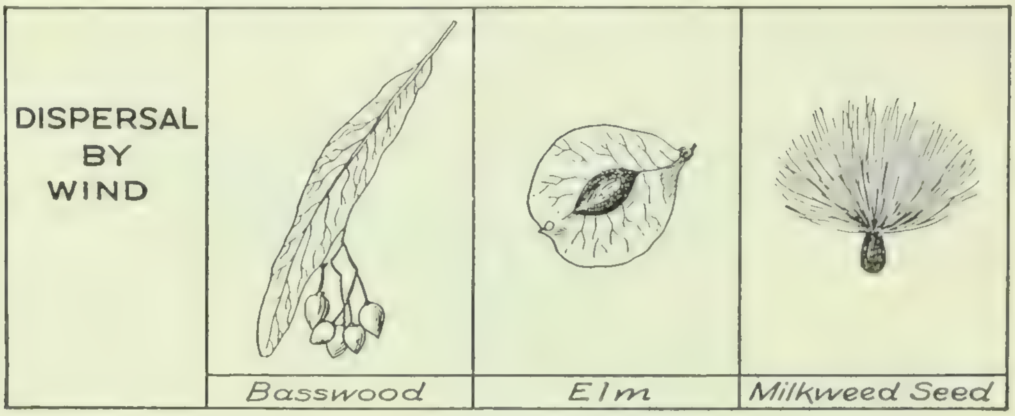


Fig. 235.

It is clearly an advantage for low-growing herbs to have some means by which the fruit may be raised high above the ground so that transference may be really effective. For this, the plumed fruits of dandelion and sow thistle are well fitted.

Very small seeds are easily borne by wind. From the 'pepper-shaker' seed container of the poppy a few light seeds are shaken out at a time and carried a short distance.

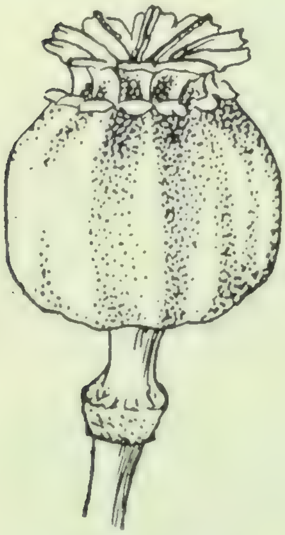


Fig. 236.

A natural 'pepper-duster': the poppy capsule.

When the fruits are ripe, the stems of Russian thistle, pepper grass and certain tumble-weeds break. Lacking the anchorage of the roots, the upper parts of the plants are blown hither and thither sowing seeds as they go.

(b) *Dispersal by water.* Many plants growing in water or along the water's edge make use of floatage as a means of dispersal. Seeds carried by the Gulf Stream from the West Indies to the British Isles have kept their power of germinating. By some it is believed that the coconut palm has been widely distributed among the islands of the Pacific by the conveyance of the nut by ocean currents. Others dispute this, claiming that, for the greater part, the distribution has been effected by man. As might be expected, water-dispersed fruits and seeds are constructed so that they float. Water lily seeds have a coat which holds air. The cranberry has a hollow, air-filled space within the berry. Many seeds are light enough to rest on the surface of the water.

(c) *Dispersal by animals.* (i) At one time or another, all of us, to our displeasure, have given rides to 'hitch-hiking' fruits, provided with hooks or prickles. Among plants scattered by wild and domestic animals in this way are the common cocklebur, burdock, avens, bedstraw, beggar-ticks and tick-trefoil.

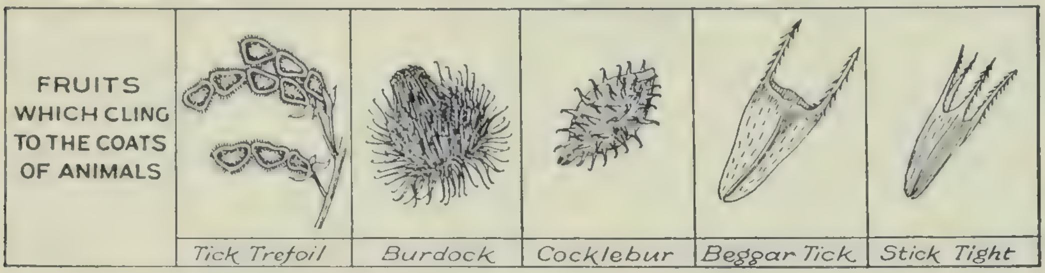


Fig. 237.

(ii) Brightly coloured fleshy fruits attract hungry birds. If the seeds are small, they frequently pass through the food tube unharmed because their hard coats prevent them from being digested. Large seeds are left when the pulpy part of the fruit is eaten.

(iii) Birds and other animals frequently carry seeds and fruits considerable distances in mud adhering to their feet.

(iv) Squirrels assist in the scattering of nuts by storing them for use in winter. Often it happens that the little animal forgets the hiding place or is killed before he can make use of the food.

(d) *Accidental dispersal by man.* Both purposely and accidentally, man has scattered fruits and seeds all over the earth. To America he has brought the important pasture grasses and all the cereals except corn. With these he has carelessly imported many kinds of weed seeds. Formerly, sand or gravel was used instead of water as ballast in ships. Before a cargo was taken on, the ballast with its thousands of weed seeds from some distant land was thrown out on the shore. With this conveyance of seeds around the world by ships we may compare their distribution of rats. Weed seeds have entered countries in the fodder brought by the cavalry of invading armies. They have been carried from farm to farm and from one field to another, in barnyard manure, machinery, packing material and wool.

The pupil will distinguish between accidental dispersal such as that above described and the scattering obtained by means of special features like wings, hair and hooks.

(e) *Dispersal by mechanical means.* If you collect some fruits of the witch-hazel and leave them on your table, you will not be permitted to forget them. Again and again, you will hear the noise which accompanies the opening of the fruit and the discharge of the smooth seeds. In spring, gather some violet fruits which have opened but still retain the seeds. If you hold these fruits loosely in the closed hand, you will realize that they also expel their seeds with some force. When the ripened fruit of jewel-weed or touch-me-not is handled, the seeds are discharged with violence. Collect some pea or bean pods and observe how the seeds are ejected.

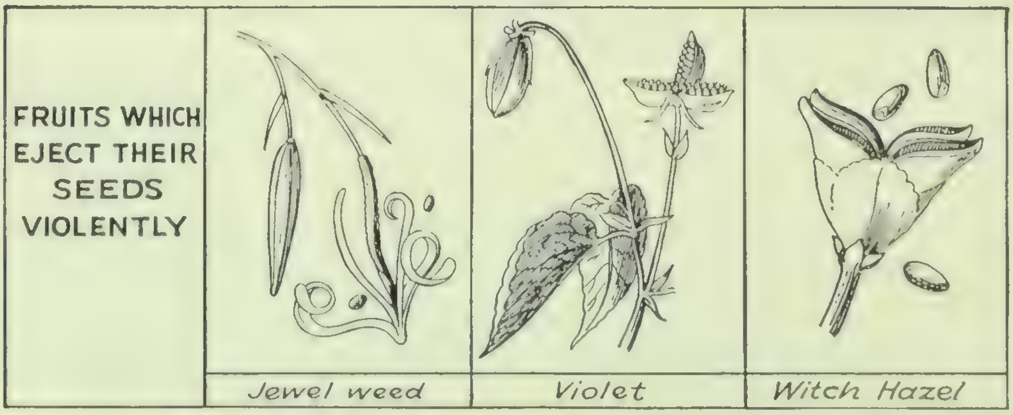

FRUITS WHICH EJECT THEIR SEEDS VIOLENTLY
Jewel weed
Violet
Witch Hazel

Fig. 238.

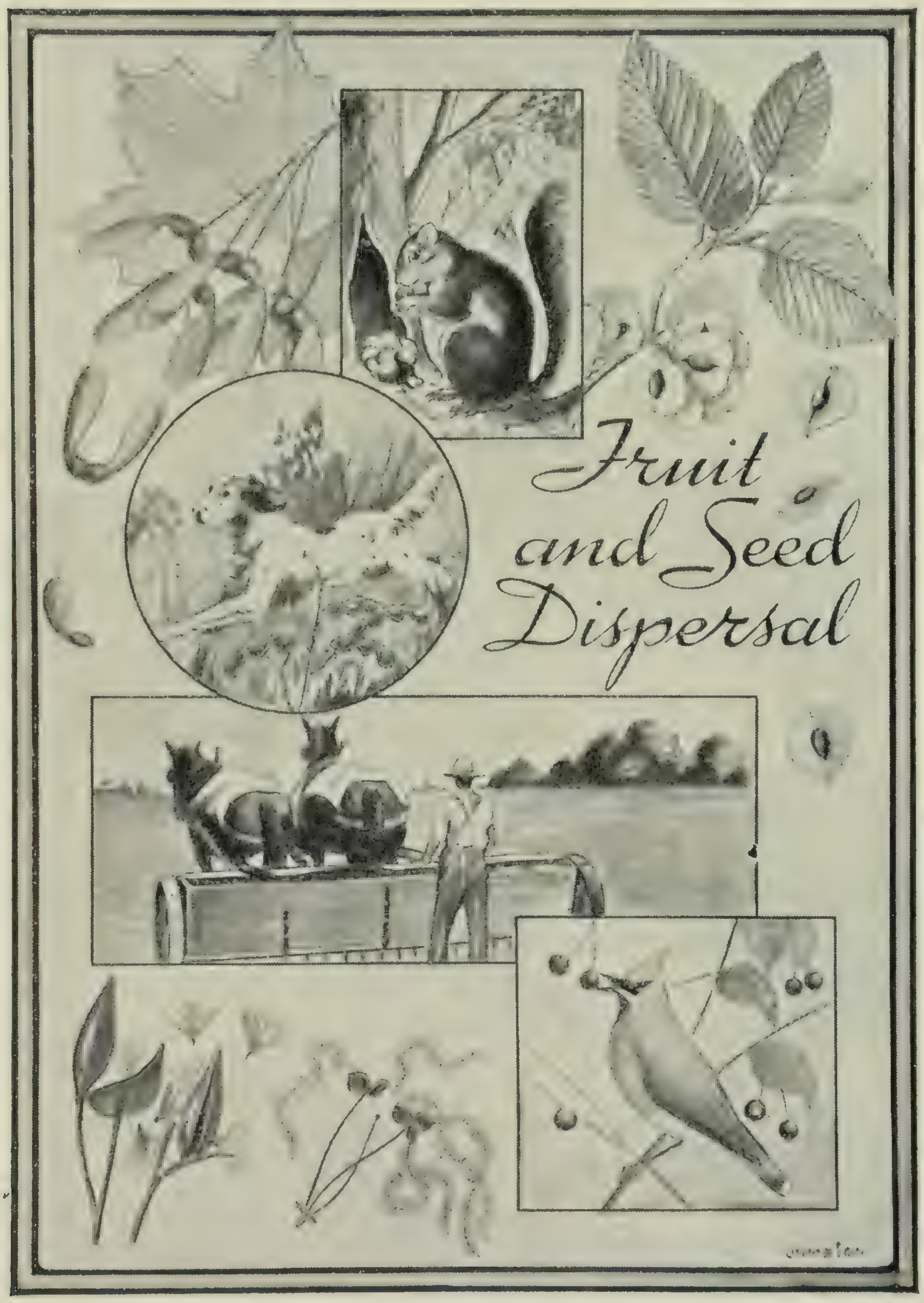


Fig. 239.

F. MINOR STUDY: What are some of the methods, other than by the production of seed, by which plants reproduce themselves?

Plants multiply by a number of methods other than by the production of seed. If you have been interested in an aquarium, you will have noticed how easily a stem of Canada waterweed is broken. Also, you will have observed that the two parts grow rapidly. Methods of reproduction, which, like the example just given, do not involve the formation of seed, are described as *vegetative.* We shall consider a number of methods of vegetative reproduction.

Bulbs.

When we grow onions from seed, the young leaves promptly begin to manufacture food, but they produce much more than the plant needs for its growth. This surplus passes downward through the leaves to be stored in their lower ends. The result is that the bases of the leaves[1] become swollen, forming a rounded structure which we call a bulb. (Fig. 240.) At the end of a year's growth, the green part of each leaf dies but the lower fleshy portion remains.

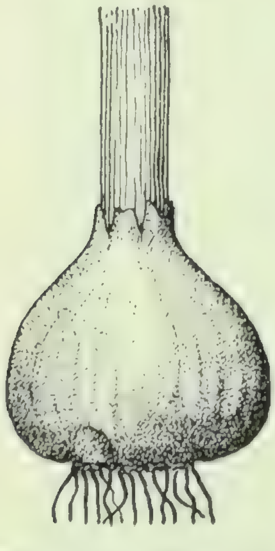


Fig. 240. The tulip bulb consists of a very short underground stem and the attached underground leaves, swollen with food.

From onion and other bulbs may be obtained small 'daughter' bulbs. The fleshy scales of the original bulb lose their store of food and are reduced to thin brown scales. These fall off and the little bulbs are set free.

Rhizomes or Rootstocks.

Numerous plants such as Canada thistle, perennial sow thistle, iris, cat-tail, sedges and couch (or twitch) grass, possess underground stems known as *rhizomes* or rootstocks. That these are really stems and not roots is shown by the presence of buds, leaves or vertical branches. Usually, these rhizomes contain stored food.

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[1] In the tulip, the fleshy scales are not the bases of foliage leaves, but are short underground leaves containing a food reserve.

Plants which have rhizomes spread very rapidly, as those who have tried to rid a garden of twitch grass know too well. The twitch grass rhizome grows rapidly through the soil forming roots and sending up green shoots at intervals.

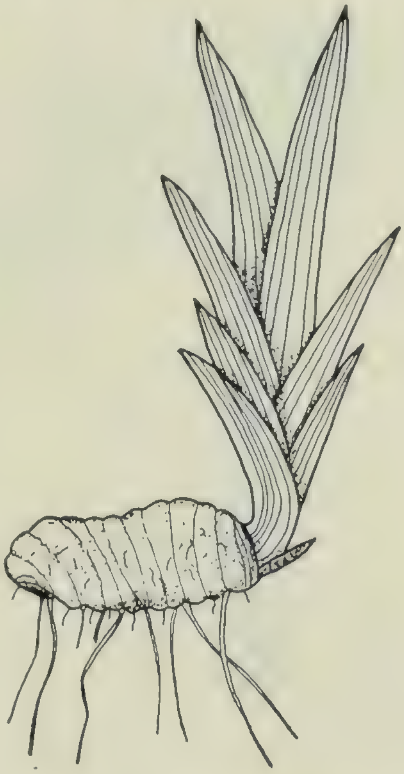


Fig. 241. The rhizome or rootstock of iris. An underground stem with a store of food.

Why is it difficult to eradicate weeds which possess rhizomes?

Dig up the rhizomes of three or four weeds and, in each case, cut the underground stem into lengths of half an inch, an inch, two inches and three inches. Plant these in boxes and mark the place where each piece of rhizome was placed. Keep the soil watered and find out if each length gives rise to a shoot. Of what practical importance to the farmer is the information gained from this experiment?

Suckers.

Red raspberry bushes send up from their roots a number of shoots which are often called ‘suckers’. These with their attached roots may be separated from the ‘parent’ bush and transplanted. Colonies of poplars formed by suckers may be seen often.

Cuttings of the stem.

To most people the cutting of geranium stems is familiar. One selects a healthy stem with several joints, and sufficiently mature to break when bent quickly. Just below one of the little swellings or nodes a clean slanting cut is made with a sharp knife. The lower leaves and some of the upper ones are then removed. The geranium slip is placed firmly in moist sand and, when roots develop after a couple of weeks, it is planted in a pot or in the garden. Cuttings made in

July or August will give bloom during the winter. If flowers are desired in the garden in summer, the cuttings should be made in spring.

Perhaps the best-known of all stem cuttings are those of the potato. A potato tuber is a reduced underground stem containing a considerable amount of stored food; the eyes are the buds, so familiar on other stems. Each 'set' planted should have several of these buds.

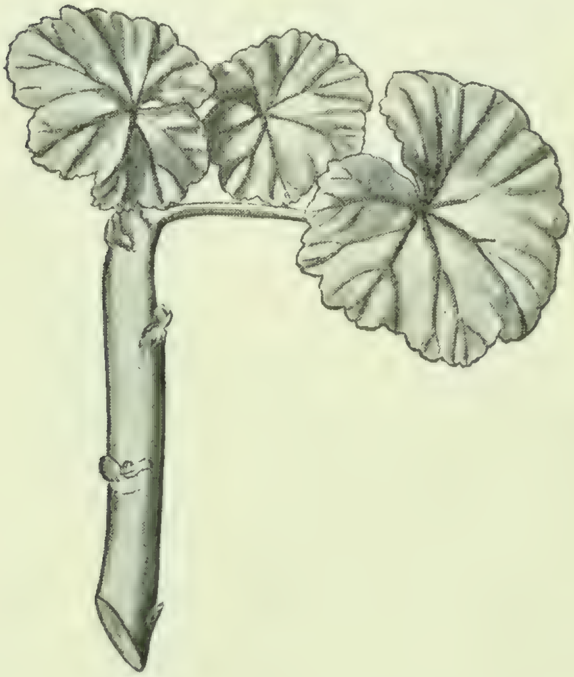


Fig. 242. A geranium cutting.

G. MINOR STUDY: Maize or Indian corn.

Up to the present we have contented ourselves with a little survey of flowering plants in which we considered their needs and the means by which these needs are satisfied. Now we shall make a careful study of one plant, maize.

Although unknown to Old World agriculture before the discovery of America, maize had been cultivated by the Indians for a very long time, so long indeed, that there is no wild plant which can be regarded as a direct ancestor. It is thought that it originated on the Mexican Plateau.

In North America the plant is called 'corn'. However, this name has been applied to a number of grain plants. For instance, the corn of the Bible is barley or rye. The historic Corn Laws of England dealt with wheat. In Ireland, the term 'corn' and 'oats' are used interchangeably. 'Kernel' and 'corn' are words with a common origin.

The roots of Indian corn.

Before digging up a corn plant, examine the aerial roots which spring from the stem a short distance above the ground. Not only do they obtain water and dissolved mineral substances from the soil, but also they brace the plant.

When the plant is removed from the soil, observe the other roots. These numerous branching roots are said to be *fibrous*. Name other plants with fibrous roots.

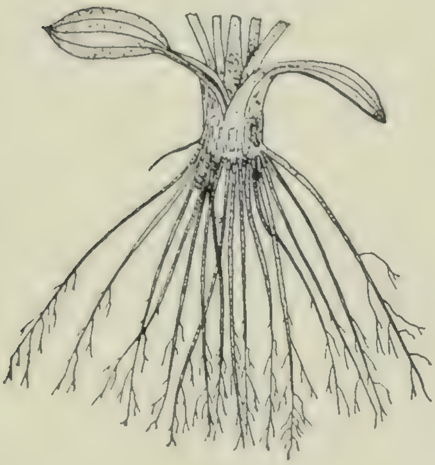


Fig. 243. The fibrous roots of common plantain.

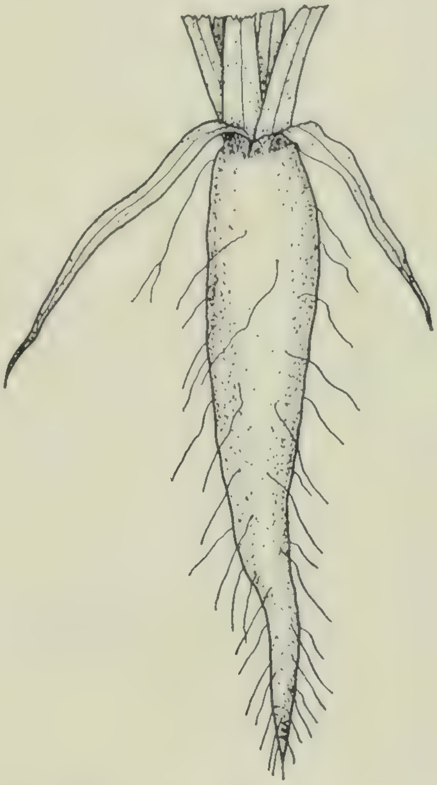


Fig. 244. The tap root of goat's beard. Food reserves are stored in this swollen root.

Compare the roots of corn with those of wild mustard. The latter plant has a *tap* root. Make a list of plants which possess tap roots.

The stem.

A chimney eighty feet high with a base just one foot wide would excite much wonder. Our interest would be increased rather than diminished if the structure were to sway gracefully in every breeze but show no tendency to collapse. This engineering feat has been performed by the corn plant and we are not impressed.

The height of the plant depends upon the variety and the locality. There are dwarf kinds about eighteen inches high having ears an inch in length. Larger types have plants twenty or more feet high, yielding sixteen-inch ears.

Examination of the stem of corn.

Describe the external appearance of a corn stem. The joints or swollen places are called *nodes*; the part of a stem between two nodes is an *internode.*

Compare the lengths of the internodes. Where are they longest and where are they shortest? What parts of the stem are strongest? Suggest a possible advantage to the plant arising from the fact that the nodes are more numerous at the lower end of the stem.

The inside of a corn stem.

Cut across through a stalk and examine the section with the naked eye and with a hand lens.

Notice the spongy pith inside the hard rind. Its property of swelling when placed in water has led to its use in the caulking of ships. Passing downward through the pith are numerous stringy structures. It is not difficult to find in the cross-section where these fibres have been cut through. Each consists of a number of cells and is known as a *fibro-vascular bundle.*

The fibro-vascular bundles strengthen the corn stalk. Also, they provide channels for the upward movement of water and for the passage downward of food substances which are manufactured in the leaves.

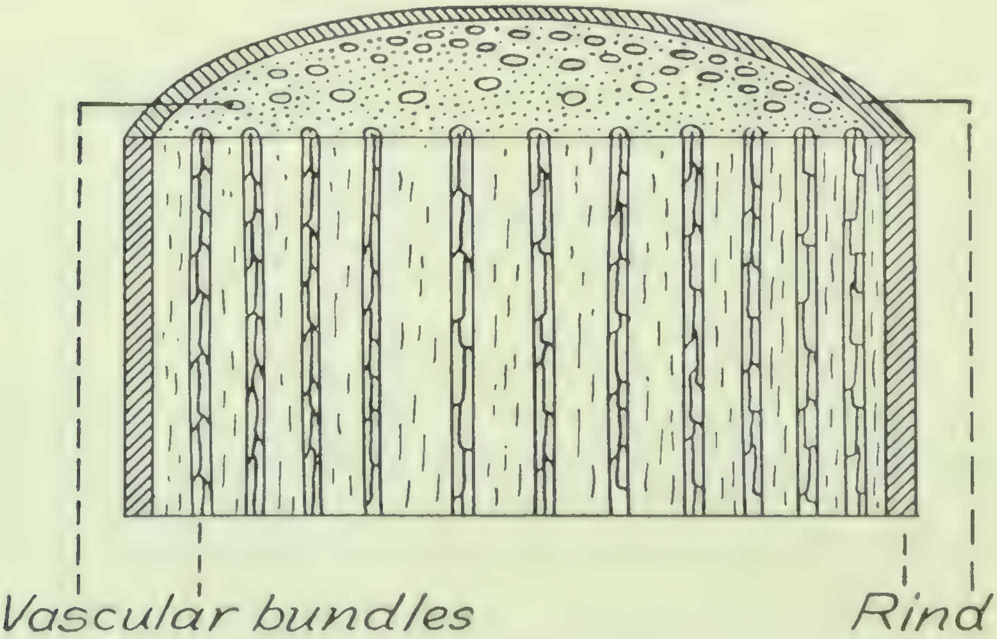


Fig. 245. In some plants, for example corn, the bundles are not arranged regularly.

In late summer, look in your flower garden for the dying stems of lilies. From these it is easy to obtain long bundles. With the aid of a little mucilage mount them on cardboard.

The 'strings' of celery and rhubarb are familiar fibro-vascular bundles.

(Recall the experiment in which geranium and poplar stems were placed in coloured water. The paths taken by the coloured water in its movement upwards were not distributed haphazardly in these stems.

There are two types of stem. In one, the bundles are scattered throughout the stem, as in the corn and tulip plants. In the other they are arranged so that in transverse section they appear as a ring. The stems of poplar, maple, geranium and pigweed are examples of the latter type.)

The nodes are the strongest parts of the corn stem. If the whole stalk were as hard as it is at the nodes, flexibility would be lost; instead of bending in the wind, the stem would break. The frequency of nodes at the base gives strength to the stem; the comparatively few nodes at the top makes for flexibility.

In some plants, for example corn and other grasses, growth takes place at the swellings or nodes as well as at the top. This may be verified by measuring at intervals the length between the nodes of growing corn. The fact that growth is not confined to one place on the stem accounts for the surprising rapidity with which corn shoots up. An interesting property possessed by corn in common with other grasses is that of being able to raise itself even when it would appear to be permanently bent. This is accomplished by more rapid growth in the region of the nodes on the side toward which the stalk is bent than in the corresponding place on the side opposite.

The leaves of the Indian corn plant.

You will recall that food substances are manufactured in the leaves and that in this work the chlorophyll has an important part. It may be pointed out here that if the stem is green it assists the leaves in photosynthesis.

Examination of the leaves of corn.

Notice how the leaves are arranged on the stem. Do the upper leaves shade the lower ones? What disadvantage to a plant would result if the lower leaves were shaded by the upper?

You will observe that a corn leaf does not spring directly from the stalk but, instead, clasps it tightly for some distance. The sheath, as this part of the leaf is called, acts somewhat like a bandage in supporting the rather delicate growing regions along the stalk

The fibro-vascular bundles extend from the roots through the stem to the leaves. In the latter they are known as *veins.* (Fig. 246). They give strength to the leaf as well as serving as channels for conducting foods and water. Frequently, we find 'skeletonized' leaves in which nothing of the blade remains but the bundles. If the leaf-scars of twigs be examined, a number of little dots may be seen. These are the ends of bundles and mark for us the places where the conducting and supporting cells entered (or left) the leaf-stalk.

How does the corn leaf behave in dry weather? This is of advantage to the plant because it prevents too great loss of water by transpiration.

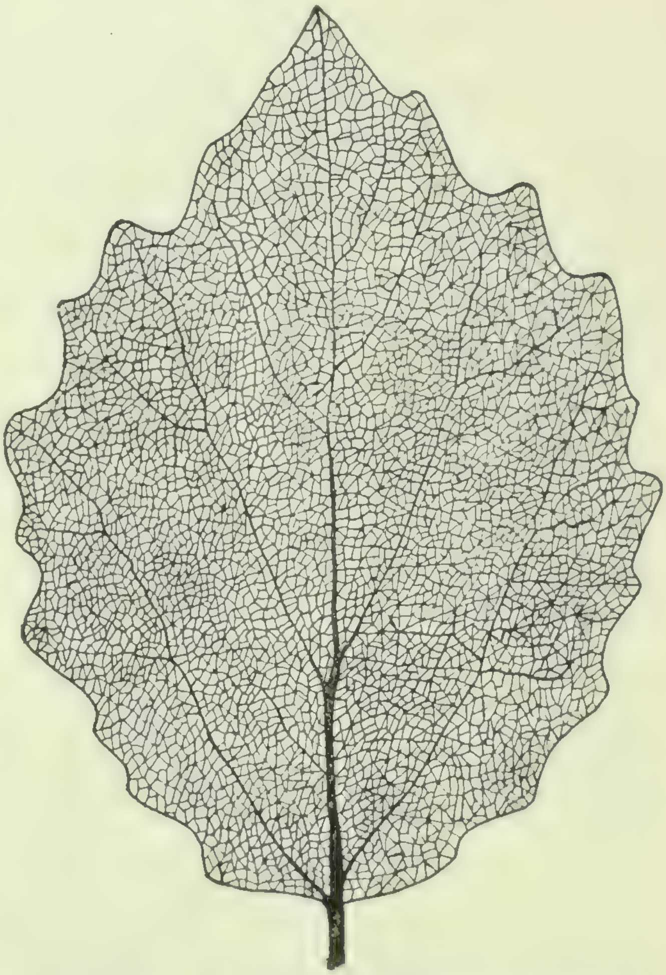


Fig. 246. A skeletonized leaf of poplar. You may find similar leaves on the ground and gain some idea of the complex system of conducting tubes and strengthening fibres.

The flowers.

Usually we do not think of corn as a flowering plant, yet it bears flowers in profusion. It is true that bright colours, marked odour and nectar are lacking; but, nevertheless, the stamens and pistils, essential for the formation of seed, are present.

To the early botanists, the corn plant's method of reproduction was a mystery "for it bringeth foorth his seede cleane contrarie from the place where as the flowers growe, which is agaynst the nature and kindes of all other plantes, which bring foorth their fruite there, where as they have borne their flower". They recognized that the *tassels*, those "idle and barren eares", were flowers; but they did not know that the *ears* also were flowers.

In the mustard plant, each flower contains both stamens and pistil, but in maize there is a separation. Stamens only are developed in the multitude of little flowers composing the tassel. The ear is made up of a number of small flowers, each with a pistil only.

Each ovary in the ear contains one ovule which, if fertilized, develops into a seed. Projecting from every ovary is a strand of 'silk' which is really a long style.

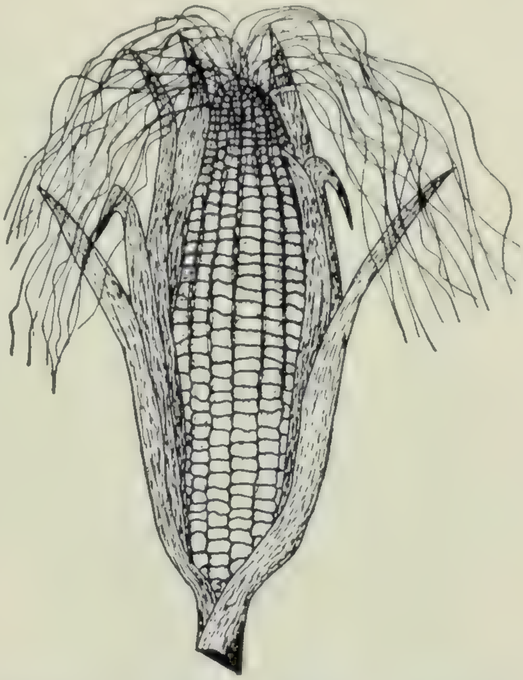


Fig. 247. Each strand of 'silk' is an elongated style and stigma.

Corn is cross-pollinated, the transference of pollen from tassel to ear being effected by wind. It is estimated that in a strong wind a pollen grain may be carried a quarter of a mile. Self-pollination is largely avoided by the fact that the anthers and ovaries do not mature together. Thus, when pollen is being shed, there are on the same plant few, if any, silk strands ready to receive it.

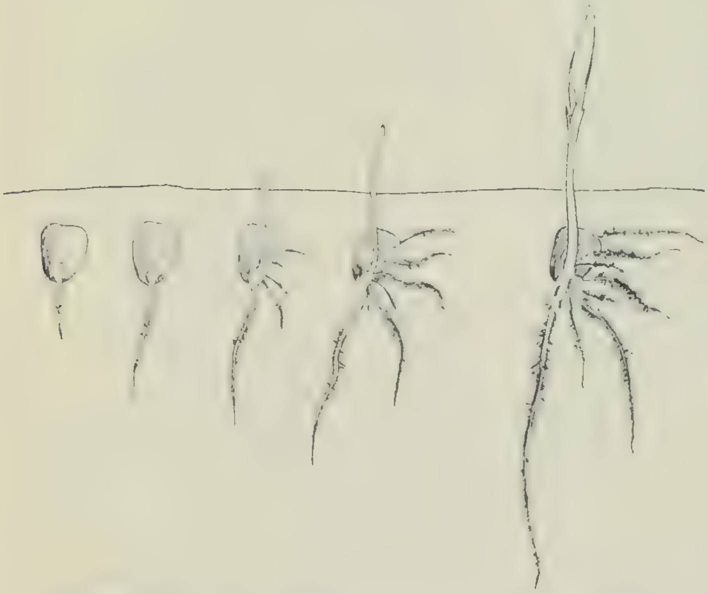


Fig. 248. Germination of corn grain.

It is said that the Indians used to spread the spores of corn smut in their fields thinking that they were the means by which the corn was fertilized.

Exercises:

(1) In what ways is corn fitted for successful living?

(2) If the prevailing winds are from the west, would you expect to find well filled ears in a single row of corn planted in the north-south direction?
Would it make any difference if the row were planted so that it ran due east?

(3) The anthers in a corn tassel produce from 18,000,000 to 60,000,000 grains of pollen, each of which can fertilize an ovule. From 600 to 2,000 ovules are formed in the ears of a plant. Using the lowest estimate for the pollen and the highest for the ovules, calculate the number of pollen grains per ovule.
Of what advantage is it to the plant that so great a surplus of pollen should be produced?

(4) Make a list of useful products obtained from corn.

(5) Make a similar study of the wheat plant.

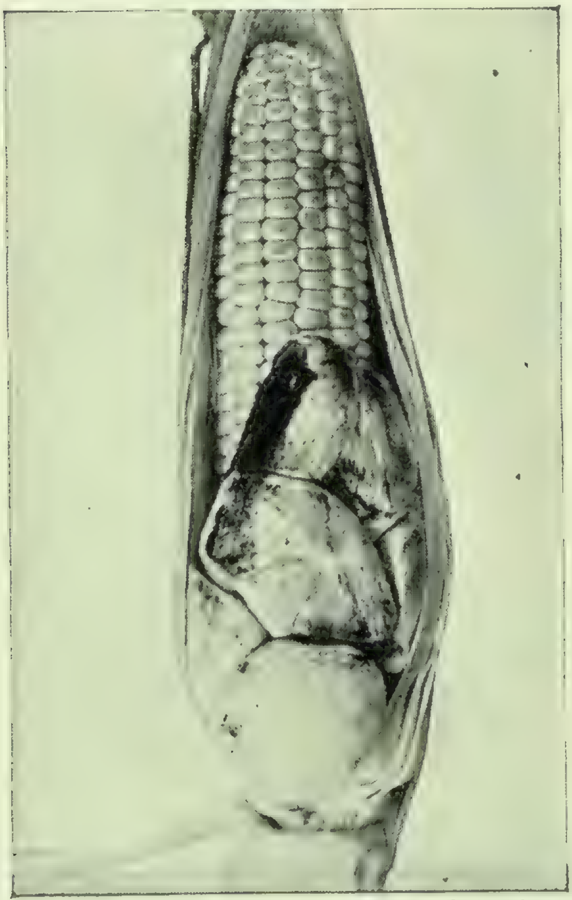

(Courtesy of the Dom. Botanist.)

Fig. 249. A smut 'boil'. The whitish skin encloses billions of spores of the parasitic fungus.

The story of a dicotyledonous stem.

There are two ways in which one may obtain material to illustrate the story of a dicotyledonous stem. One could secure a young seedling, one somewhat older, a second-year plant of the same kind, and so on. Another, and more convenient method, is to cut across a twig very close to its end, and then to make sections in parts which are progressively older. (Figs. 250-252.)

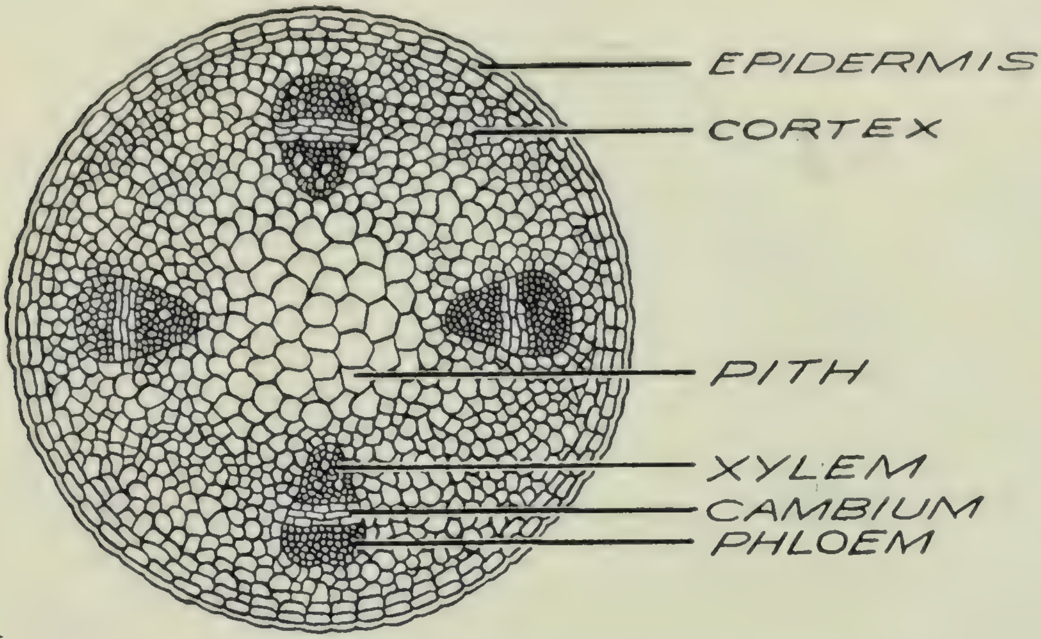


Fig. 250. A young dicotyledonous stem.

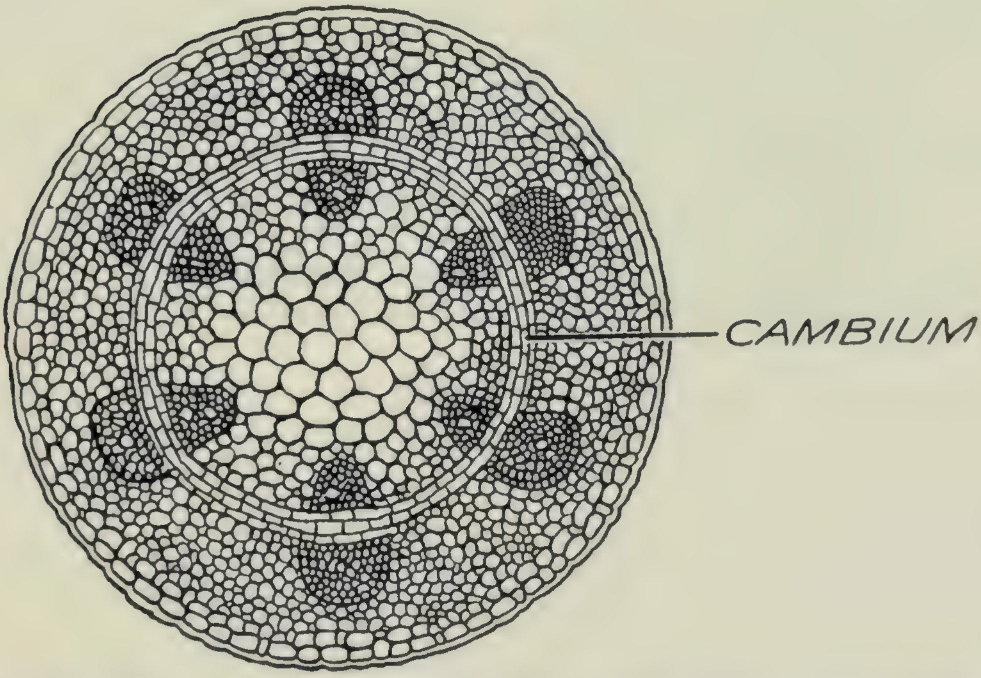


Fig. 251. The stem is now somewhat older. Notice the increase in the number of bundles and the formation of cambium between them.

In the young stem the bundles are not continuous. As we have already mentioned, the xylem is at the inner part of each bundle, and the phloem at the outer. Between the two is a very thin layer of cells known as the *cambium*, (Fig. 250).

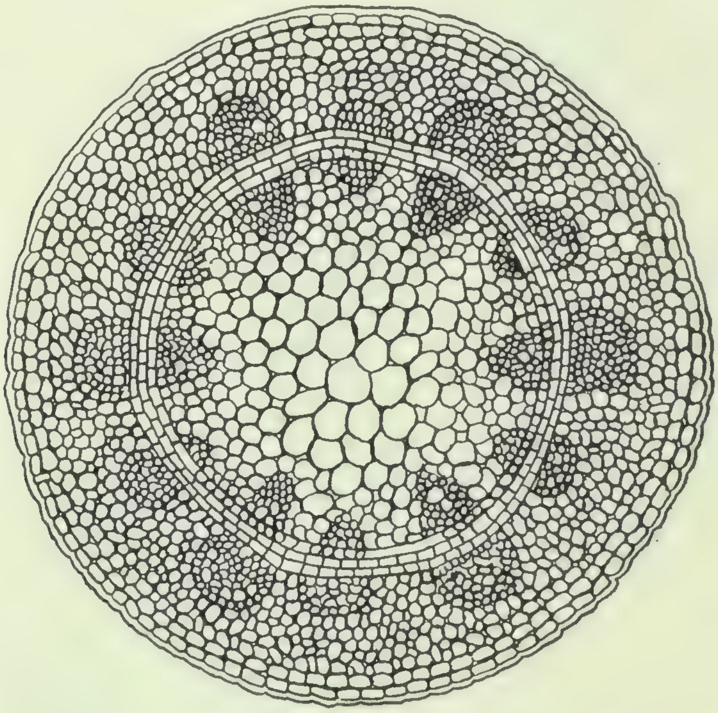


Fig. 252. The stem is a little older than that represented in Fig. 251.

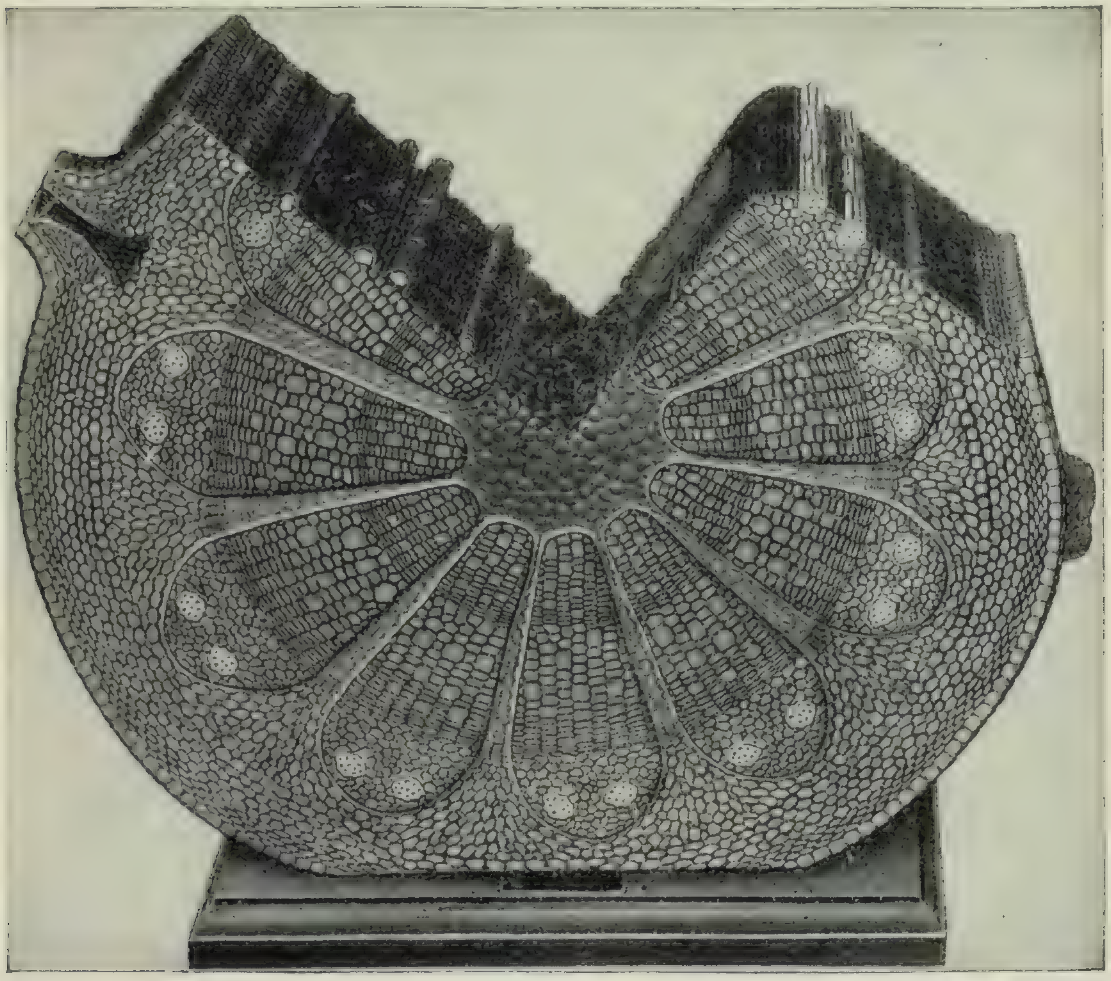
(While studying transverse sections it should be borne in mind that the parts observed extend upward and downward.)

H. **MINOR STUDY**: **What may be learned from stumps, tree trunks, and twigs?**

A section of an older dicotyledonous stem reveals an increase in the number of bundles and an extension of the cambium to form a ring. (Figs. 250 and 251.) In reality, the cambium is now a cylinder.

This increase in the number of bundles continues, so that at the end of the first year they form a cylinder around the central *pith*. It will have been noticed that the parts of the pith which extended outward between the bundles have become more and more compressed, so that now they are quite thin. These are known as *medullary rays*. (Figs. 253, 254 and 255.)

The cambium cylinder between xylem and phloem is just a few cells thick and can be seen only with the aid of a microscope, but it is of very great importance. Its inner cells form wood or xylem; its outer ones produce the phloem in the soft inner bark. Thus, it is continually bringing about an increase in the thickness of the stem, and, since its position is always on the outside of the xylem, it is yearly re-



(Courtesy of Jewell Models.)

Fig. 253. Photograph of a model of a dicotyledonous stem. Notice the ring of bundles surrounding the central pith. In the phloem at the outer ends of the bundles are cells represented in the figure by light-coloured patches. These are the cut ends of strengthening fibres. Find the longitudinal sections of two groups of strengthening cells. Not far from the inner side of the fibres, and separating the phloem from the xylem are the cambium cells. Notice that they extend between the bundles, forming a ring.

ceding from the centre. It is most remarkable that the activity of this extremely thin cylinder of cells is responsible for the increase in diameter of dicotyledonous plants, including our largest trees.

The cambium and home-made whistles.

Most boys know how to make a whistle from a twig of willow, basswood, or mountain ash. The piece of stem is bruised until the epidermis and soft layer underneath it slip together off the woody cylinder. (This soft layer includes the phloem.) The bruising ruptures the delicate cambium cells and thus makes the desired separation easily effected. Because of the greater activity of the cambium in spring, and the presence in it of abundant liquid, the rind is most easily removed in that season. The moisture, seen on the outside of the wood after the rind is stripped off, is derived from the cambium.

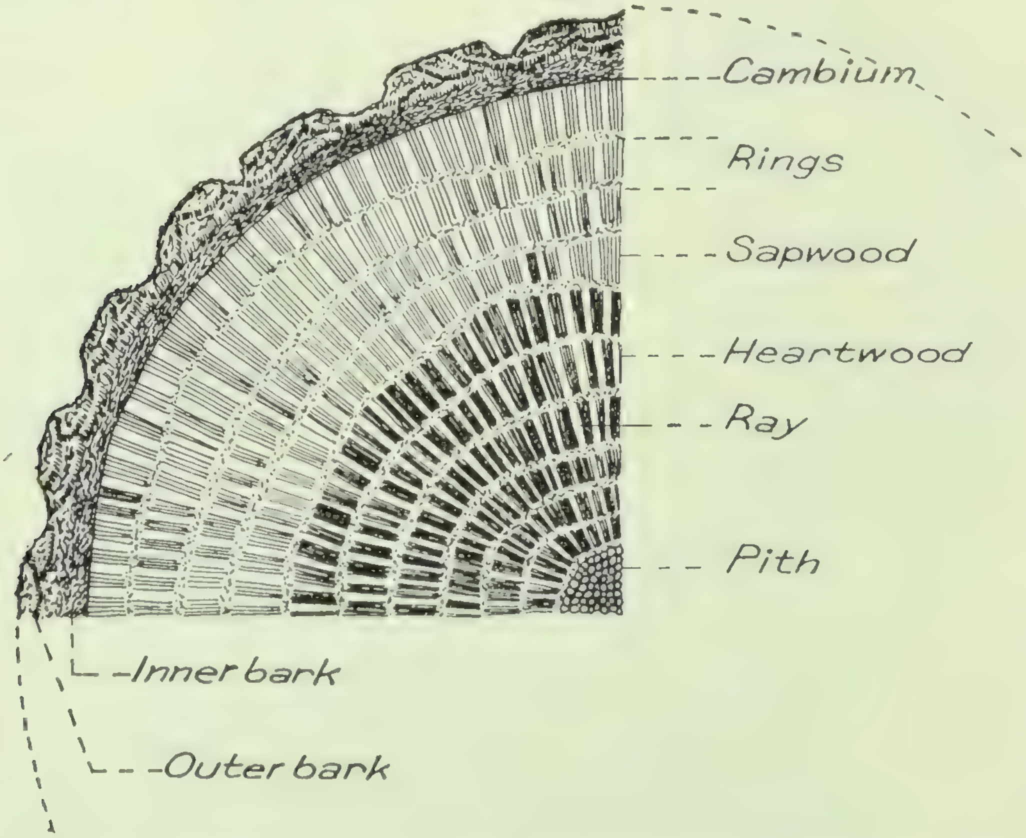


Fig. 254. A mature woody dicotyledonous stem. Year after year, the cambium formed wood or xylem on its inner side until a considerable thickness was attained. The phloem is in the soft inner bark.

As the stem grows older, the epidermis is replaced by a corky bark composed of dead waterproof cells. In a number of trees, the wood around the centre loses its power to conduct water, becomes dark due to the deposition of resin and other substances in the cell walls, and dies. Then it is called *heartwood.* The remaining wood, which has many living cells, provides a passage for the water. It is relatively light in colour and is known as *sapwood,* (Fig. 256).

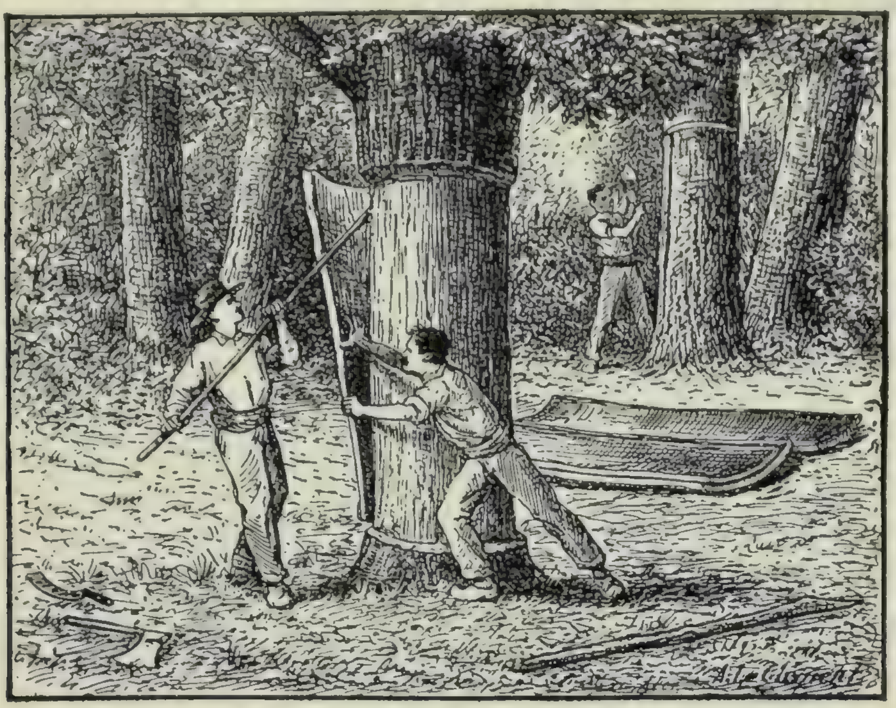


Fig. 255. The removal of cork from the cork oak. After Lecomte.

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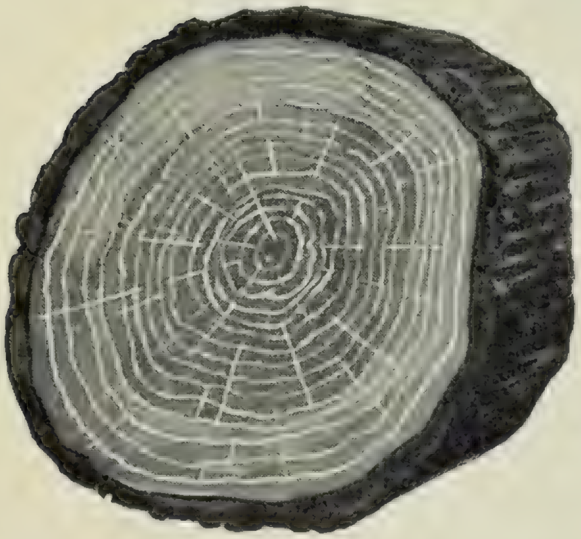

Fig. 256. The dark central heartwood consists of dead cells which no longer conduct water upward from the roots. Water moves upward through the cells of the lighter-coloured sapwood.

The sapwood, while of little value as lumber in comparison with heartwood, is clearly of much more importance to the tree.

The medullary rays.

The rays are narrow

bands of cells which serve to conduct food and water across the diameter of the stem. They are used also as storage places for starch.

Much of the beauty of quarter cut oak is due to the rays which are exposed, (Fig. 257 B).

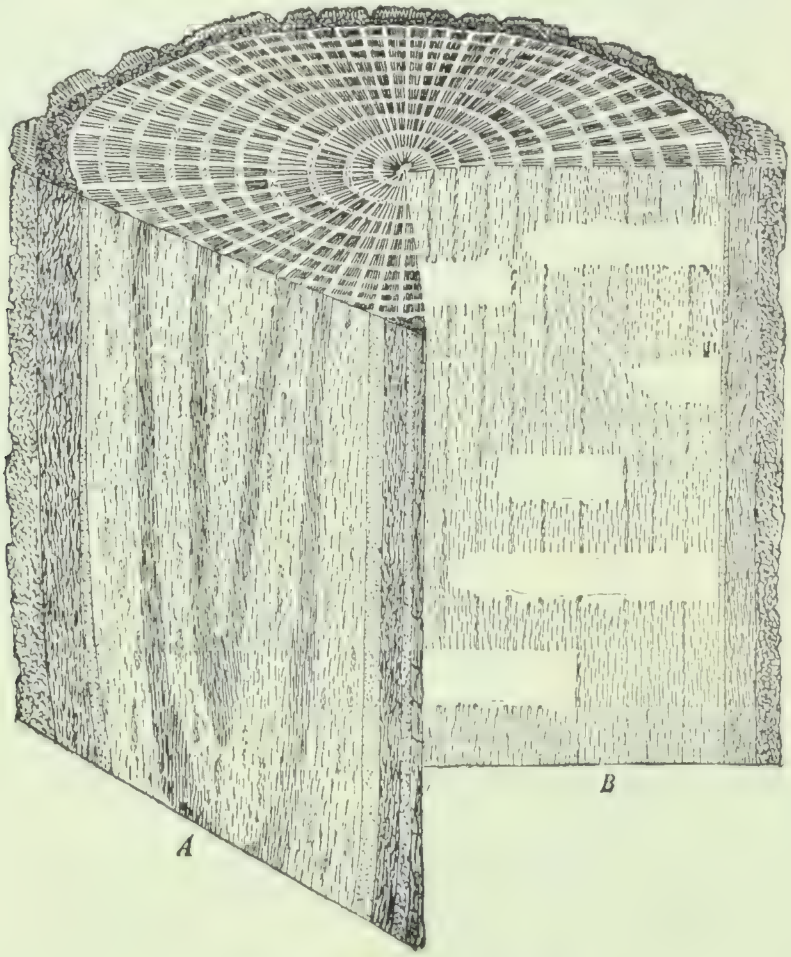

Fig. 257. An oak log.

At B the log is sawn in a direction parallel to that of the rays in this region. Boards obtained thus are described as 'quarter cut.' The light-coloured patches on the surface B in the figure are sections of rays.

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How to tell the age of a tree.

If a woody dicotyledonous stem be examined even casually, a number of rings will be seen. Since one is formed each year, the age of the tree is easily determined.

In spring, the cambium is active in producing new wood. The conducting vessels in this new growth are large and have relatively thin walls. During the summer, the rate of formation of the wood is reduced. The cells are smaller and their walls are thicker. These differences in the appearance of the wood give us the annual rings. In tropical regions, where there is no clearly marked seasonal change, rings are lacking.

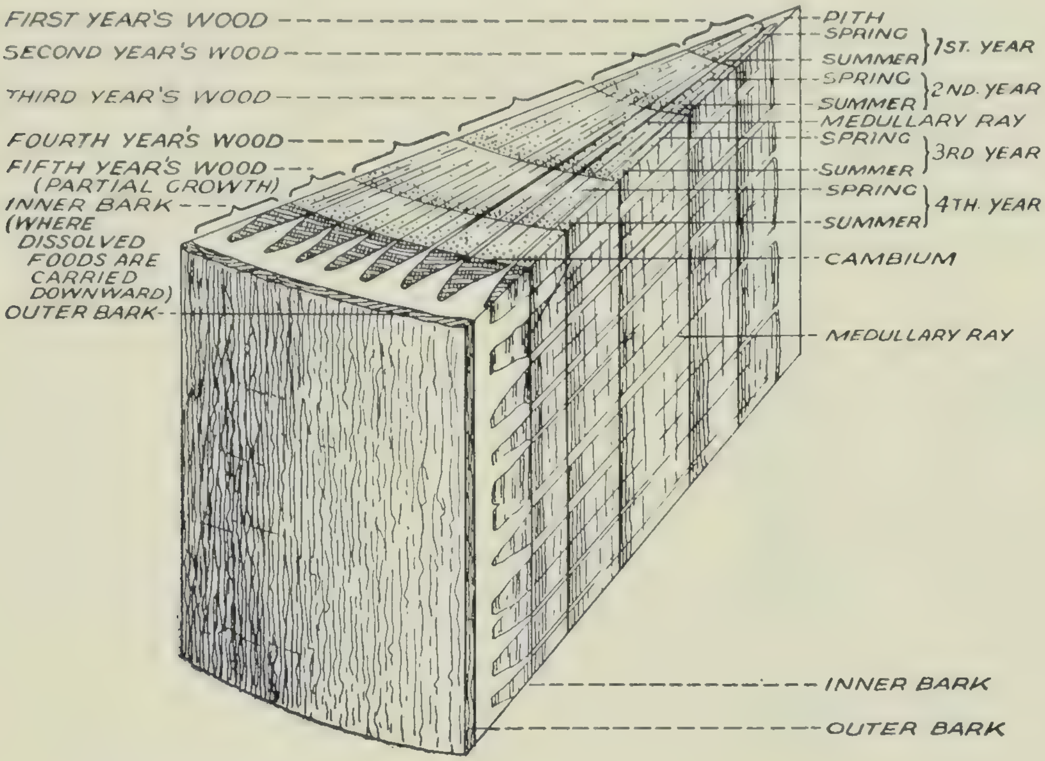

Fig. 258. Portion of a tree trunk in its fifth year.

When lumber is *plain sawn*, that is to say, perpendicularly to the rays, (Fig. 257A), its attractiveness is due largely to the pattern formed by the sections of the annual rings.

The stems of monocotyledons.

There is no cambium between the xylem and phloem of plants like corn, the lilies, and bamboo, hence there is very little increase in diameter.

The architecture of stems.

We have seen that in woody dicotyledonous stems there is a hard central cylinder. In herbaceous dicotyledons, the stem dies down after it has completed a year's growth. Consequently, there is insufficient time for the production of a large mass of wood. It is of interest to learn how these stems are fitted to support considerable weights.

At first, the unconnected fibro-vascular bundles serve as girders to strengthen the stem. Later, they form a cylinder around the pith. Engineers know well that a hollow column gives maximum strength for a given weight of material, so that whenever lightness and economy of material must be combined with strength this device is employed. We may notice that it is used in the construction of high buildings and in bicycle frames; we see it in quills and in the hollow bones of birds. The cylinder surrounding the pith of the herbaceous dicotyledonous stem provides us with another example.

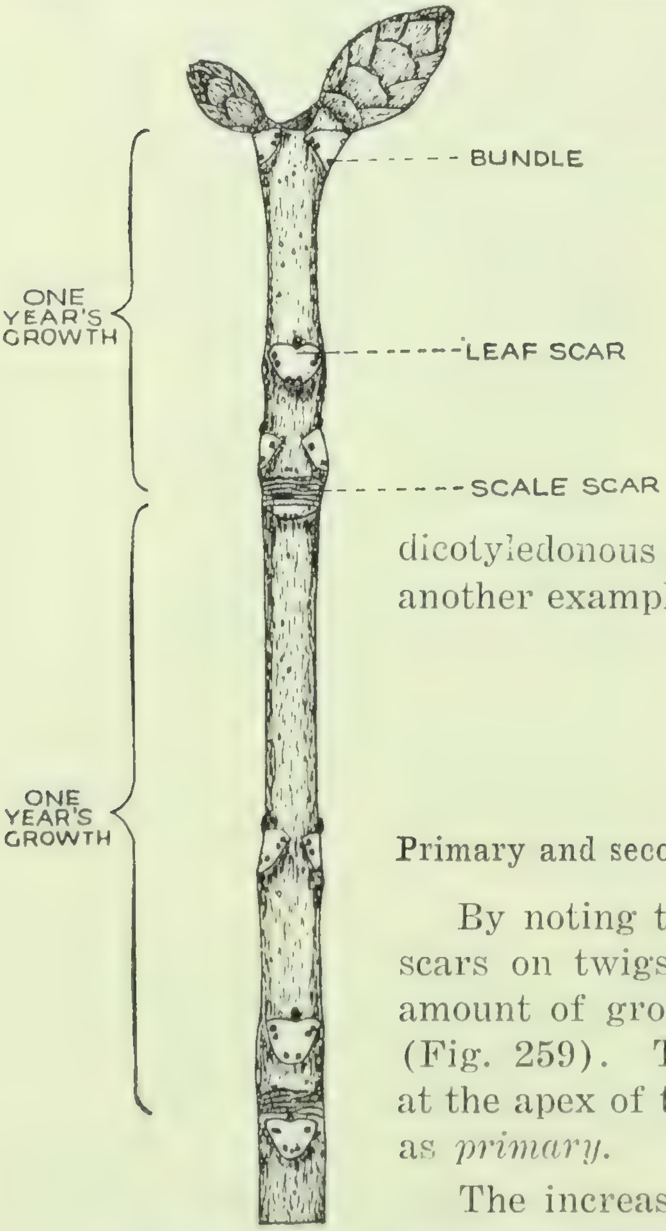

Fig. 259.

Primary growth in a horse chestnut twig.

Primary and secondary growth.

By noting the positions of the scale scars on twigs, we can determine the amount of growth in successive years, (Fig. 259). This growth takes place at the apex of the stem and is described as *primary*.

The increase in diameter of dicotyledonous stems due to the activity of the cambium cylinder is described as *secondary* growth.

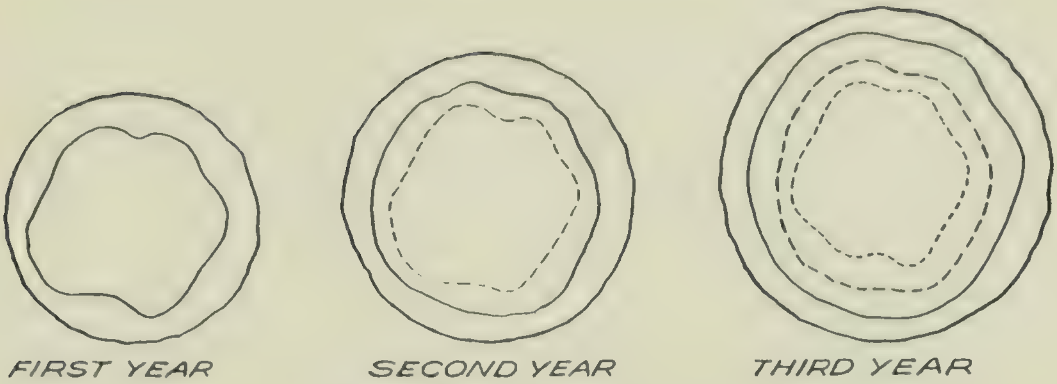

Fig. 260. Secondary growth.

The inner continuous lines show the position of the cambium cylinder at the end of one, two and thee years. Its former positions are indicated by the dotted lines.

Exercises:

(1) Fruit growers sustain loss from time to time through the girdling of trees by rabbits and mice. Describe how girdling may injure or kill a tree.

(2) Frequently, we see apparently healthy trees from which the heartwood has disappeared. Explain why the tree can remain alive.

(3) Explain why the spile should not be driven into the heartwood when a maple tree is tapped.

(4) How can you tell the age of (a) a twig, (b) a trunk?

(5) What evidence is there that some stems take part in photosynthesis?

TOPIC VII—THE UNIVERSE

*"The heavens declare the glory of God; and
the firmament sheweth His handywork."*

Only those who are dull of soul or thread-bare in imagination lack a sense of wonder and reverence when they look at the sky on a starry night. Most people catch a glimpse of the immensity and mystery of the universe, and when they turn their minds once more to their own affairs, these seem strangely dwarfed. Our feeling of the sublimity of the heavens is not diminished by increased knowledge, rather it is increased a thousand-fold.

UNIT 11. MAJOR STUDY: Space is vast and contains a great number of bodies moving in an orderly relation to each other.

A. MINOR STUDY: Astronomers have made great progress in understanding the vast spaces of the universe.

PROBLEM I: Why do people seek to learn about the heavenly bodies?

It may appear to some that astronomy, or the study of the heavenly bodies, is a rather useless subject. Yet we depend upon the astronomers to tell the correct time. Before the in-

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The outdoor observations suggested in this chapter may be begun soon after the opening of school in September. Star maps should be available for guidance. The following are recommended: the *Observer's Handbook*, published by the Royal Astronomical society of Canada, 198 College St., Toronto, price 25 cents; four maps obtainable from the Director of University Extension, University of Toronto, price one cent each; the *Star Explorer*, published by the Junior Astronomy Club, Hayden Planetarium, New York City, price 25 cents each, discount of 20 per cent if 25 are purchased; (the *Star Explorer* gives the location, at any hour of each day of the year, of stars which are visible in most parts of North America;) *Constellation Charts*, supplied by Popular Astronomy, Northfield, Minn., price 15 cents. A journal for amateur astronomers, *The Monthly Evening Sky Map*, may be obtained at 244 Adams St., Brooklyn, N.Y. Each issue contains a star map and gives information concerning the planets. Yearly subscription, $2.00.

vention of the compass, sailors used the stars as guides and they still make astronomical observations in order to fix their position at sea.

From the earliest times men have searched the skies. Shepherds on the hills and priests on the towers have looked and wondered. Like those who see faces in glowing coals, they traced among the stars the outlines of gods and animals. Just as we find it difficult to see in a fire the pattern that is so clear to our friend so we are not greatly impressed by the resemblances that appealed to the star-gazers some thousands of years ago. Nevertheless, we keep the ancient names.

Astrology.

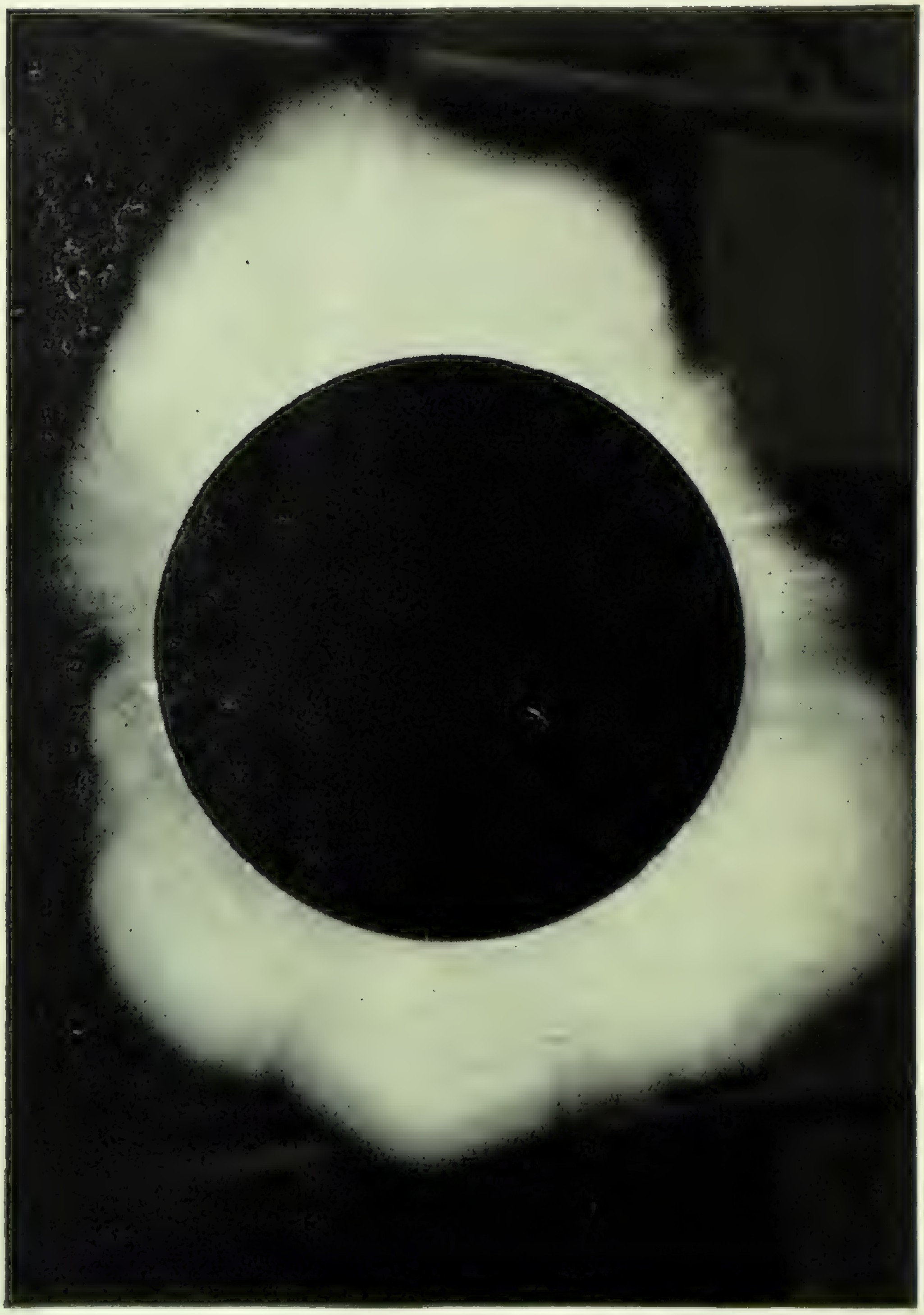
In our study of biology we learn that animals and planets frequently harbour parasites. Nearly every science has a parasitic false-science practised for their advantage by unscrupulous men at the expense of followers who, although easily deceived are hardly more ignorant than their leaders.

Down through the ages there have been, and there still are, astrologers who pretend that their knowledge of the stars makes possible the foretelling of the future.

PROBLEM II: What inventions contributed to the advancement of our knowledge of the heavens?

We learned that Galileo in 1610 was the first man to use a telescope to study heavenly bodies. Men discovered that our solar system is but part of the universe. Galileo was also the first man to attempt a measurement of the speed of light. Two men with screened lanterns were placed on hills several miles apart. An attempt was made to measure the passage of light between the observers. The result was very inaccurate. When men discovered the speed of light, they were able to find how far away the stars are from us. The spectroscope led to an understanding of the composition of heavenly bodies.

(NOTE: Ask your teacher to tell you where you can find a description of a spectroscope.)



(*Courtesy of Mount Wilson Observatory.*)

Fig. 261. The corona: a silvery halo which surrounds the sun and which is visible only during a total eclipse. At a distance of some 400,000 miles from the surface of the sun the corona has a temperature of about 4000° C.

B. MINOR STUDY: The sun is the source of energy for all the bodies revolving around it.

The sun.

At an average distance of ninety-three million miles from us is the vast seething furnace on which we depend for heat and light. Without this heat, the rivers, lakes and seas would be completely frozen, and every living thing on the earth would quickly die. At its surface, the sun has a temperature of about 6,000 degrees Centigrade; it is believed that in the interior the temperature is many millions of degrees.

The sun, spherical in shape, has a diameter of 865,000 miles, over a hundred times that of the earth. Its volume is more than one million times the earth's.

No doubt, you have noticed in a casual manner the daily path which the sun appears to take across the sky. Since our work, our amusements, and our hours of rest are influenced by the position of the sun in the heavens, you may wish to make more systematic observations.

Observations on the position of the sun at different times on a single day.

(It is very harmful to the eyes to look directly at the sun. A piece of smoked glass should be used.)

By reference to some building or feature of the landscape, observe where the sun rises.

Notice its position in the sky a number of times throughout the day.

At what time was the sun highest in the heavens?

The hourly changes in the length and direction of a shadow cast by the sun are of interest.

How a shadow alters as the position of the sun changes.

Set a straight stick vertically on a flat piece of ground so that there is a length of three or four feet showing above the soil. Prepare a number of small pegs and by means of them mark the end of the shadow at different times throughout the day. Begin as early as possible in the morning and continue until late in the afternoon. During the period from 11.30 a.m. to 12.30 p.m., insert the pegs at five minute intervals. At other times, it will be sufficient if the end of the shadow is marked every hour. Write on each peg the time at which it was placed in the ground.

Describe the changes that took place in the length and direction of the shadow as the day advanced.

At what time was the shadow shortest? What was its direction at this time? In what position was the sun? With the aid of a diagram, explain why the shadow is shortest when the sun is highest.

Find two pegs, one inserted in the early forenoon, the other in the afternoon, which are the same distance from the stick. Calculate the period which elapsed between the time when the first peg was placed in position and when the length of the shadow was least. Obtain the corresponding period for the other peg. Compare these two times. What is the direction of a string attached to the pegs? With the aid of a diagram, explain why the string should have this direction.

(The time at which the shadow is shortest is known as apparent or solar noon, (Lat. *sol*, the sun). As the time between successive solar noons, or in other words, the solar day, varies, it is impossible to construct a clock which will always agree with sun-time. Hence, we adopt as our day the average length of all the solar days in the year. The difference you may have observed between solar noon and clock noon is partly due to this cause.)

When travelling by automobile or train, you have noticed that the trees, the fields and the houses appear to rush past in the direction opposite to that in which you are moving. Once every twenty-four hours, the earth makes a complete rotation on its axis, as the imaginary line joining the North and South Poles is called. The direction of rotation is from west to east. We are not conscious of this movement; it seems to us that the earth is at rest and that the sun is travelling from east to west. This rotation of the earth on its axis is the cause of day and night.

PROBLEM I: Does the sun always rise (or set) at the same place on the horizon?

The apparent movement of the sun across the sky is not the only change which may be noticed by an observer. It is suggested that over a considerable period observations be made on the positions of the sun at dawn, at noon, and at sunset.

Further observations on the sun.

By reference to features of the landscape, mark the positions of the sun at dawn and sunset at intervals of one or two weeks. Observations should be made on September 23rd, December 21st, March 21st, and June 21st, or on dates very close to these. Note also the position of the sun at noon.

By reference to the *Observer's Handbook* or a daily newspaper find the duration of daylight on the 7th, 12th, 19th, 21st, 22nd, 23rd and 30th of each of the four months mentioned.

In your notebooks make a table similar to that which follows and complete the entries.

Date	Position of sun at dawn	Position of sun at noon	Position of sun at sunset	Duration of daylight
Sept. 23				
Dec. 21				
Mar. 21				
June 21				

Further observations on a shadow.

Keep a record of the lengths of the shadow cast by a stick at noon at intervals of one or two weeks.

Compare the lengths of the shadows on December the twenty-first and June the twenty-first. (Dates close to these may be substituted.) What is the cause of the difference?

PROBLEM II (a): Why does the sun rise and set farther to the north on June the twenty-first than it does on December the twenty-first?

PROBLEM II (b): Why is it higher in the heavens on the first day than on the second?

PROBLEM II (c): Why is there more daylight in June than in December?

Once every 365 days, 5 hours, 48 minutes, and 46 seconds, the earth travels around the sun at a speed of about 18½ miles per second. The earth's axis is not perpendicular to the plane of the earth's orbit, but is always tilted at an angle of 23½ degrees.

The orbit of the earth is the path along which it travels in revolving around the sun. By 'the plane of the orbit' is meant the imaginary flat surface on which every point of this path lies. Ignoring perspective in Fig. 263, the plane of the orbit is the page on which the line is drawn.

During part of the year, the North Pole leans towards the sun. As a result, in northern lands the sun is high in the sky and we have summer. At this time the sun rises at points north of east. When the South Pole leans towards the sun, there is southern summer and northern winter. Then the sun rises to the south of east. The northern hemisphere is most inclined towards the sun on June 21st, the southern on December 21st. On the first mentioned of these dates, the days are longest in the northern hemisphere and shortest in the southern. On the second date, the opposite is true.

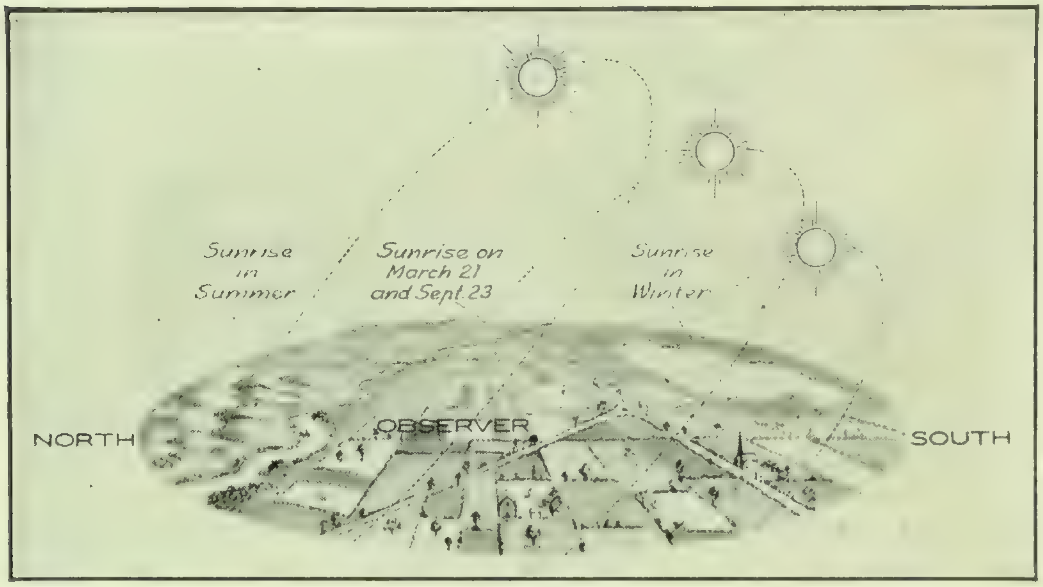


Fig. 262. The changes in the positions of the sun at dawn and at sunset.

On March 21st and September 23rd, the sun's rays just reach both poles, and throughout the world day and night are of equal length. These dates are called respectively the vernal and the autumnal equinox, (Lat. *aequus*, equal; *nox*, night). On them, the sun rises and sets due east and west of the observer.

In the northern hemisphere, spring begins on March 21st, summer on June 21st, fall on September 21st, and winter on December 21st.

C. MINOR STUDY: The moon is the earth's closest neighbour in space

The moon with her placid face and golden light has long cast an influence over the minds of men. We are not surprised at the many superstitions concerning what should or should not be done at certain changes, the eggs that should be set, the seeds that should be sown. Once it was believed that those afflicted with insanity were affected by the moon, and we still have a link with this in the word 'lunatic', (Lat. *luna*, moon). Poets have expressed the vague feelings of those who look wonderingly on the "orbed maiden with white fire laden."

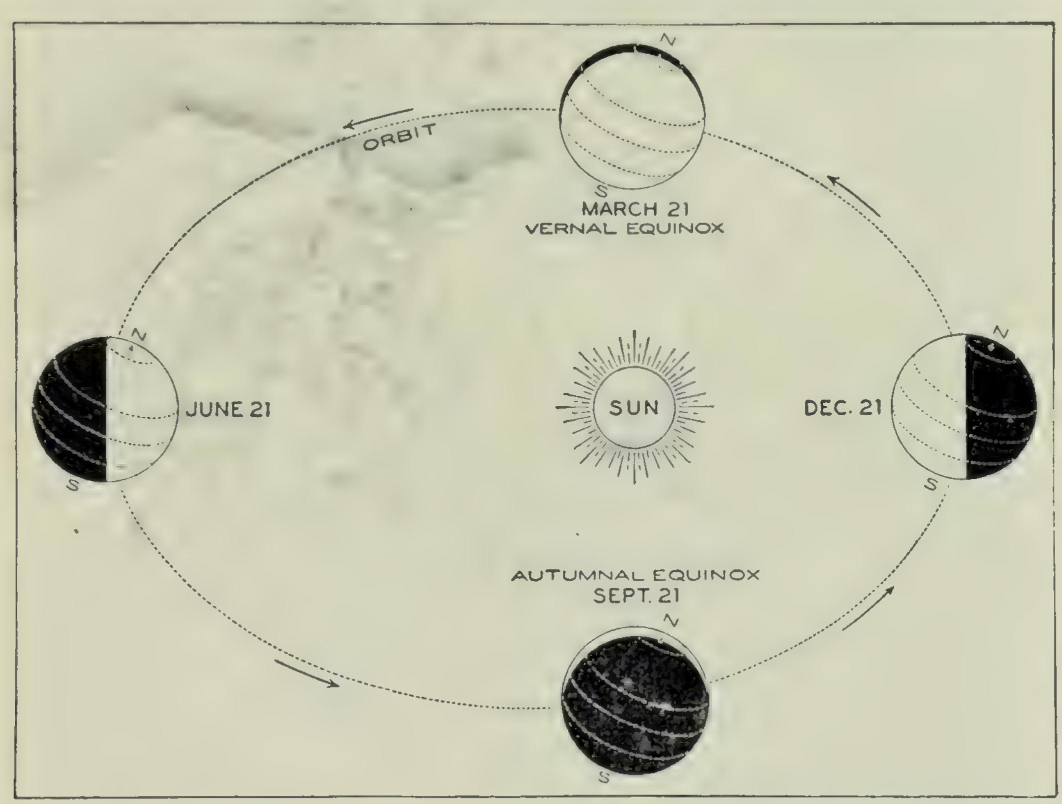
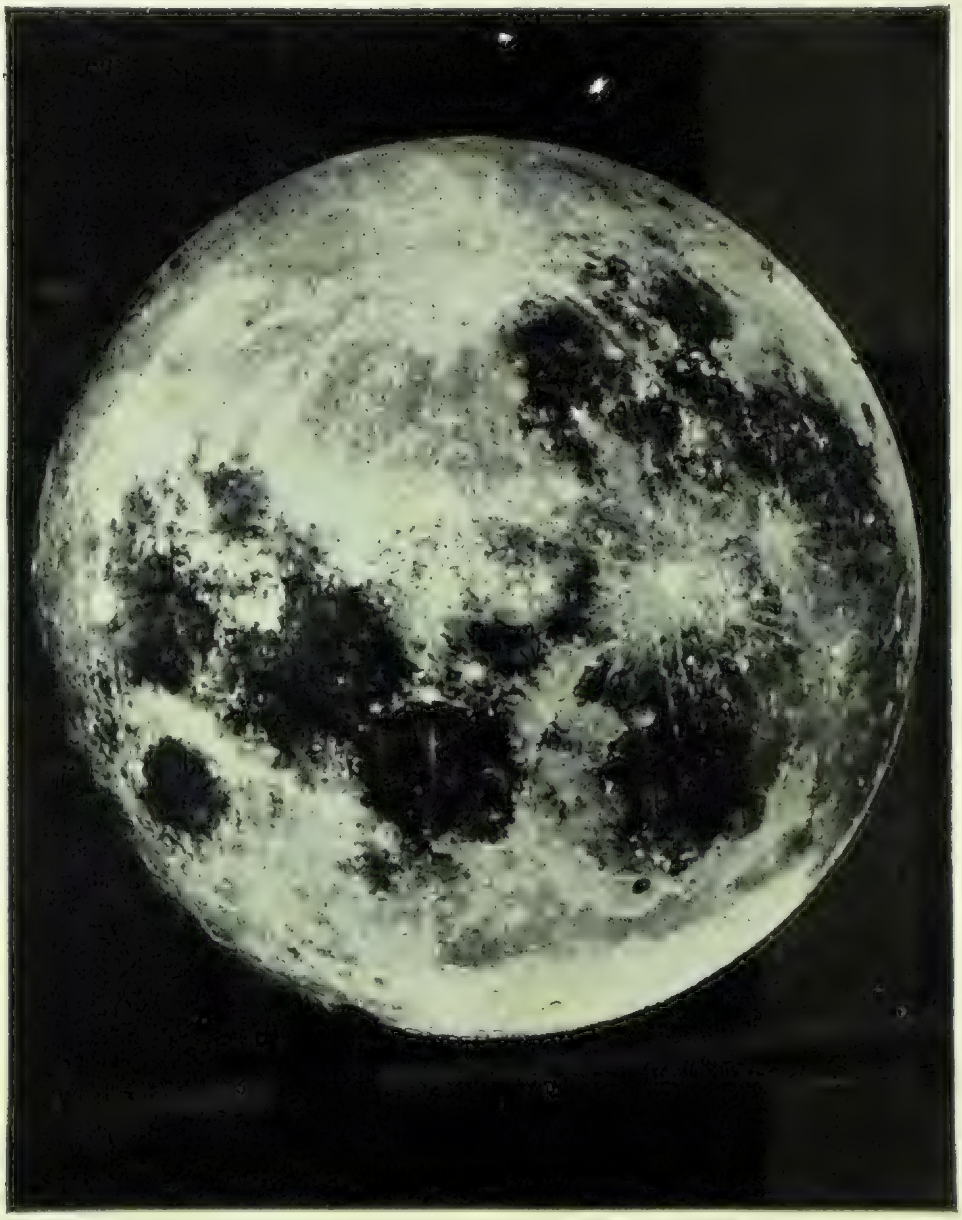


Fig. 263. The inclination of the earth's axis has results which influence life profoundly.

The moon is the earth's next door neighbour in the heavens being, on the average, rather less than a quarter of a million miles away. Powerful telescopes reveal that the surface is rugged, creased into lofty mountain ranges, and pitted with thousands of craters the diameters of which are in some cases as much as a hundred miles. Since there is no atmosphere and no water, the rocks are not weathered like those of the earth and the mountain peaks are jagged. Some think that the craters were caused by volcanic action, others that they were produced by meteors falling on the surface. The moon is a sphere with a diameter of 2,160 miles. Its volume is about one-fiftieth that of the earth.



(*Courtesy Photographic Agency.*)

Fig. 264. The moon as seen through a telescope.

Unlike the sun and like the earth, the moon has no light of its own. It appears to be luminous because of the sunlight reflected from its surface, (p. 385). If we could visit this neighbour of ours, we would see the earth above us like a great moon, which, when 'full', would have about four times the diameter of the full moon we see from the earth.

Because of the lack of atmosphere, the moon's surface becomes as hot during the day as boiling water; at night, the temperature falls several hundred Fahrenheit degrees below zero. Day and night on the moon are always equal, each lasting about two of our weeks.

PROBLEM I: What changes take place in the moon's appearance?

Find out the date of a new moon. Can the moon be seen on that night? Look for the moon on successive nights and record when it can be seen first.

In what part of the heavens is the crescent seen first? In what direction do the horns point? Make observations on the position of the moon at intervals of ten minutes. Where does the moon set? What is the direction of the apparent movement of the moon? Suggest why the moon is usually invisible until after sunset.

At the same time on the next night observe the position of the moon again. In what part of the heavens is it seen? Compare the positions in which it was seen on this and on the previous evening. Repeat these observations at the same time on other evenings.

On successive nights notice the changes in size of the crescent. How old is the half moon? What is its position when first seen? In what direction is the convex side turned?

What is the age of the moon when it is full? In what part of the sky is it first seen at this stage?

After the moon is full, which side gradually decreases? In what direction do the horns point? Note the times of moonrise on two successive nights. What is the difference between them?

As a co-operative enterprise, observations should be made on as many nights as possible during a complete cycle of changes.

PROBLEM II: What are the apparent and real movements of the moon?

When the moon is new, no light is reflected to us from its surface.[1] Two or three days later we see the thin crescent in the west soon after sunset. After a short time, it sets in the west.

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[1] This is not strictly true because of light reflected from the earth to the dark side of the moon. The effect of this 'earthshine' is apparent when the moon is a few days old.

At the same time on the following evening, the moon is higher in the sky but still in the west. Night after night at the same time, we see it farther and farther to the east and note that it moves towards and sets in the west. Finally, we see it rising on the eastern horizon. This seems confusing. However, the matter is not really difficult if we know the earth and moon move.

Let us deal first with the journey from east to west. Like the apparent daily movement of the sun, this is not real. Because of the earth's rotation on its axis from west to east, we imagine that the moon is travelling from east to west. Due to the sun's light, we are usually unable to observe this apparent movement across the sky in daytime.

The movement of the moon to the east is real and is due to its revolution around the earth from west to east. Because of this journey from west to east, fifteen days after the moon was new we see it on the eastern horizon at sunset. For the same reason it is below the eastern horizon at sunset on the following nights and we are now able to note the time of moonrise. On the average, this time is about forty-eight minutes later each night, and so it is eventually necessary for us to leave our beds early in the morning in order to see the old moon. The changes in the moon's appearance are completed in a period of about 29½ days.

How the earth and moon move.

Let us imagine a boy running around an almost circular path. Not content with his forward motion, he indulges at the same time in the strange amusement of turning round and round. Close to him is a smaller boy who displays even greater activity. Not only does he travel along the course with his companion, but also he moves around him. As if this were not enough, the little fellow succeeds in turning his own body once every time he runs around his friend. The big boy is the earth rotating on its axis and revolving around the sun; the little one is the moon rotating on its axis and revolving around the earth.

(Due to the fact that the moon rotates once on its axis while making a revolution around the earth, it has always the same side turned towards us.)

D. MINOR STUDY: The planets vary in size and distance from the sun.

PROBLEM I: What heavenly bodies make up our solar system[1]?

When we likened the earth and moon to two boys running round a track, we overlooked much of the whole scene. Besides the earth (and its companion) there are eight other large globes moving around the sun. Like the earth, most of them have satellites or followers; these are called moons. The nine spheres surrounding the sun are called planets. This name, derived from the Greek for 'wanderer', was given to the worlds which revolve around the sun because they change their positions among the stars.

Closest to the sun is the planet Mercury, then in order come Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto discovered in 1930.

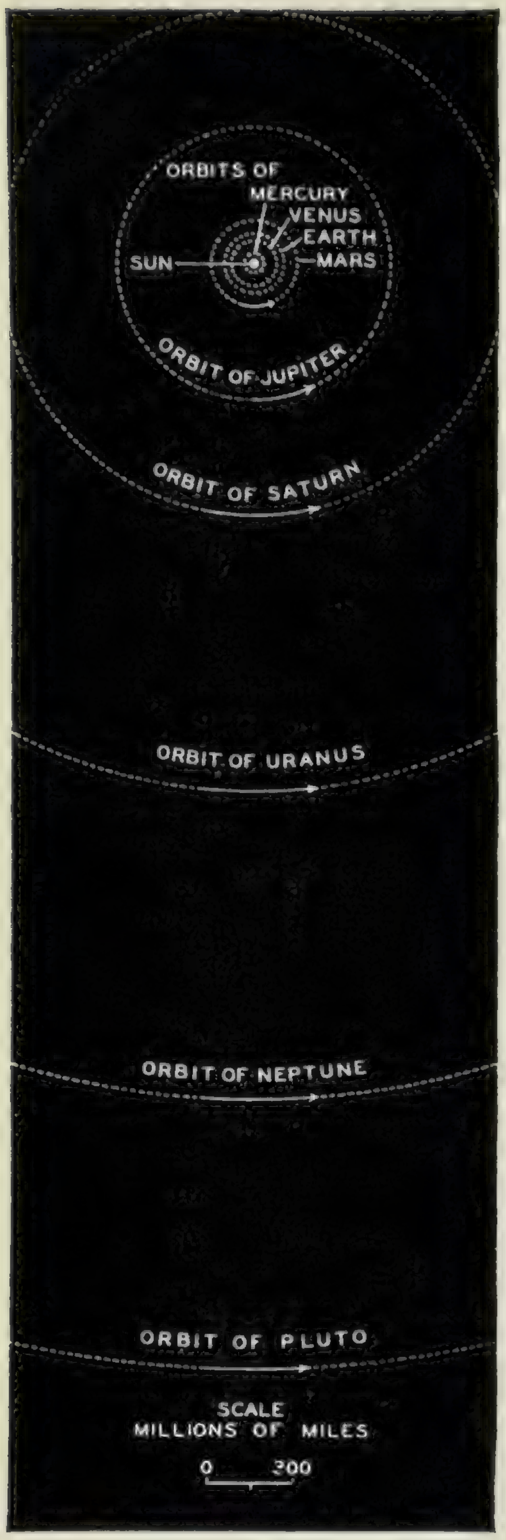

Fig. 265.

This illustration will give you some idea of the relative distances of the planets from the sun.

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[1] It is suggested that after a brief discussion of the planets some observations be made on the stars. Later, more time may be devoted to observation and discussion of the planets.

Mercury the smallest of the planets is at the relatively small average distance of 36,000,000 miles from the sun. Its year, the time taken to revolve around the sun, is only 88 of our days. Mercury, after whom the planet was named, was the messenger of the gods.

Venus is nearest in size to the earth and is the most brilliant of the planets. There is a possibility that some form of life may exist on it. The planet is called after the goddess of love and beauty.

The Earth and its moon would be seen shining in the heavens by dwellers—if such exist—of other planets.

Mars is named after the Roman god of war probably because of its ruddy appearance. There has been much speculation as to whether or not the planet is inhabited by intelligent beings. Some have held that the markings or 'canals' on the surface of the planet are evidences of the existence of a high order of life. A number of theories have been advanced to account for the 'canals' but agreement on the subject is lacking.

Jupiter, with a volume of about 1,300 times that of the earth, is the largest member of the sun's family. Its average distance from the sun is about 483,000,000 miles. Since it makes one revolution around the sun in a little less than 12 years, its year is nearly 12 times that of the earth. Twelve moons revolve around the planet. The name is that of the king of gods.

Saturn, named after the god who was Jupiter's father, is somewhat smaller than Jupiter and about 400,000,000 miles farther from the sun. If we examine it with even a small telescope, we see that it is surrounded with a bright ring. Astronomers have found that there are really three rings, one inside the other They are composed of swarms of small satellites or moonlets. In addition to these, Saturn has at least nine moons. The specific gravity is so low that the planet would float if sufficient water were provided.

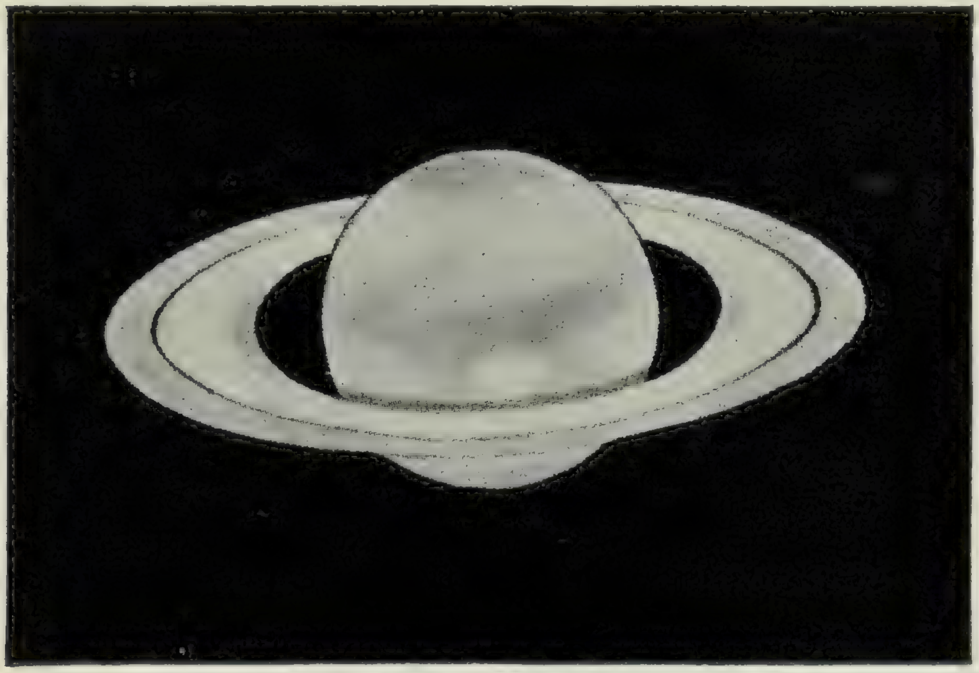
Uranus, Neptune, and *Pluto* are the most remote of the known planets. The last named is at the colossal distance of 3,700,000,000 miles from the sun.

It should be mentioned that there are many tiny planets or asteroids, mainly between the orbits of Mars and Jupiter. The paths of more than 1,000 of these have been determined. Their diameters range up to five hundred miles; most are considerably under fifty.

Observation of planets.

It may be of assistance to the pupil in distinguishing the planets from the fixed stars if he remembers that usually the latter twinkle and the former shine steadily.

At the proper time, five planets, Mercury, Venus, Mars, Jupiter and Saturn may be seen with the unaided eyes. It is recommended that the *Observer's Handbook* and the *Monthly Evening Sky Map* be consulted.



From "Through My Telescope" by W. T. Hay (Dutton).

Fig. 266. The planet Saturn and its rings. The ring farthest from the planet has a diameter of about 186,000 miles and a breadth of 10,000; its thickness is only about 100 miles. These rings consist of swarms of small satellites or moonlets.

Observe the position of one planet from night to night.

Using a good pair of field glasses, try to find the moons of Jupiter. There are four large enough to be seen.

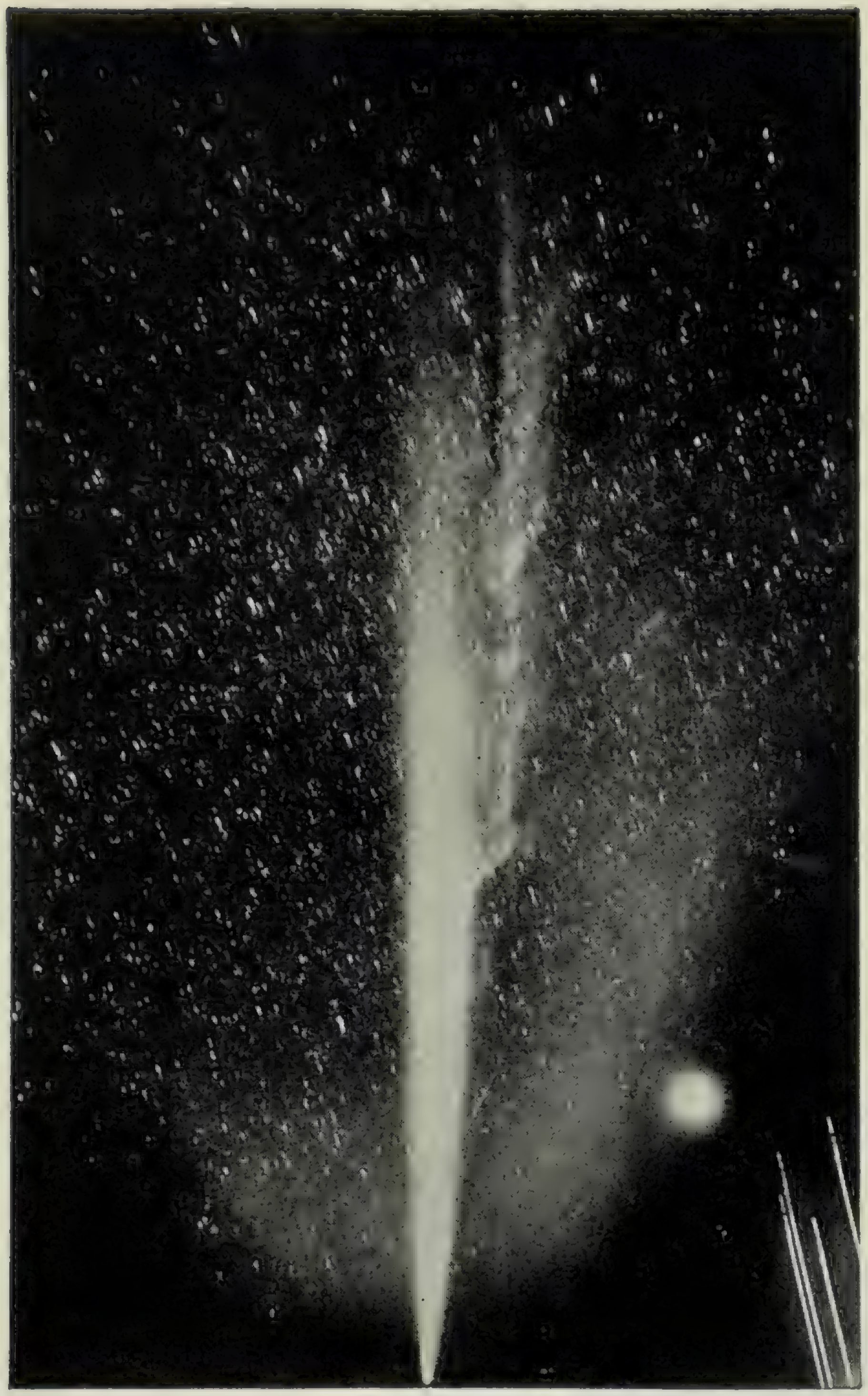
The sun, the nine planets and their moons, the asteroids, meteors, and some comets belong to what is known as the solar system. The immensity of this system is altogether unimaginable. To reach the orbits of the planets, a ray of light travelling at 186,000 miles a second would require the following times after it left the sun:

Mercury	3 mins.	**Mars**	13 minutes	**Uranus**	2 hrs. 42 mins.
Venus	6 mins.	**Jupiter**	44 minutes	**Neptune**	4 hrs. 14 mins.
Earth	8 mins.	**Saturn**	1 h. 20 mins.	**Pluto**	5 hrs. 36 mins.

We may try to form some idea of the size of the solar system from the following model. Imagine a globe of one foot radius at the centre of a circular field a mile and three-fifths in radius. Let this globe represent the sun. Then the sizes of the planets and their distances from the sun may be roughly repeated as follows:

Planet	Radius	Dist. from sun
Mercury	1/25 inch (Mustard seed)	84 feet
Venus	1/10 inch (Small pea)	155 feet
Earth	1/10 inch (Small pea)	215 feet
Mars	1/16 inch (Matchhead)	327 feet
Jupiter	1¼ inch (Orange)	$\frac{1}{5}$ mile
Saturn	1 inch (Tangerine)	$\frac{2}{5}$ mile
Uranus	2/5 inch (Cherry)	$\frac{3}{4}$ mile
Neptune	3/5 inch (Walnut)	$1\frac{1}{5}$ miles
Pluto	1/20 inch (Mustard seed)	$1\frac{3}{5}$ miles

Up to this time, we have assumed that the sun stands still. This is not the case; the solar system is moving as a whole, relatively to the 'fixed' stars, at a speed of 12 miles a second in the direction of the star Vega. Locate this star on the star map, Fig. 269.



(Courtesy of Lowell Observatory.)

Fig. 267. Halley's comet.

This photograph is the result of an exposure of thirty-five minutes, during which the camera was kept in motion. The 'trails' in the right corner are due to city lights. Near them is the planet Venus. Notice the fine meteor 'trail' near the head of the comet.

Data on the Solar System.

Name	Average distance from sun in millions of miles	Average diameter in miles	Mass compared with that of earth	Volume compared with that of earth
Sun	....	864,000	332,000	1,300,000
Mercury	36	3,010	0.056	0.06
Venus	67	7,580	0.82	0.88
Earth	93	7,918	1.00	1.00
Mars	142	4,220	0.11	0.15
Jupiter	483	87,000	318.	1,314.
Saturn	886	72,000	95.	765.
Uranus	1783	31,000	14.6	59.
Neptune	2793	33,000	17.2	72.
Pluto	3666	4,000(?)	Less than .1	......

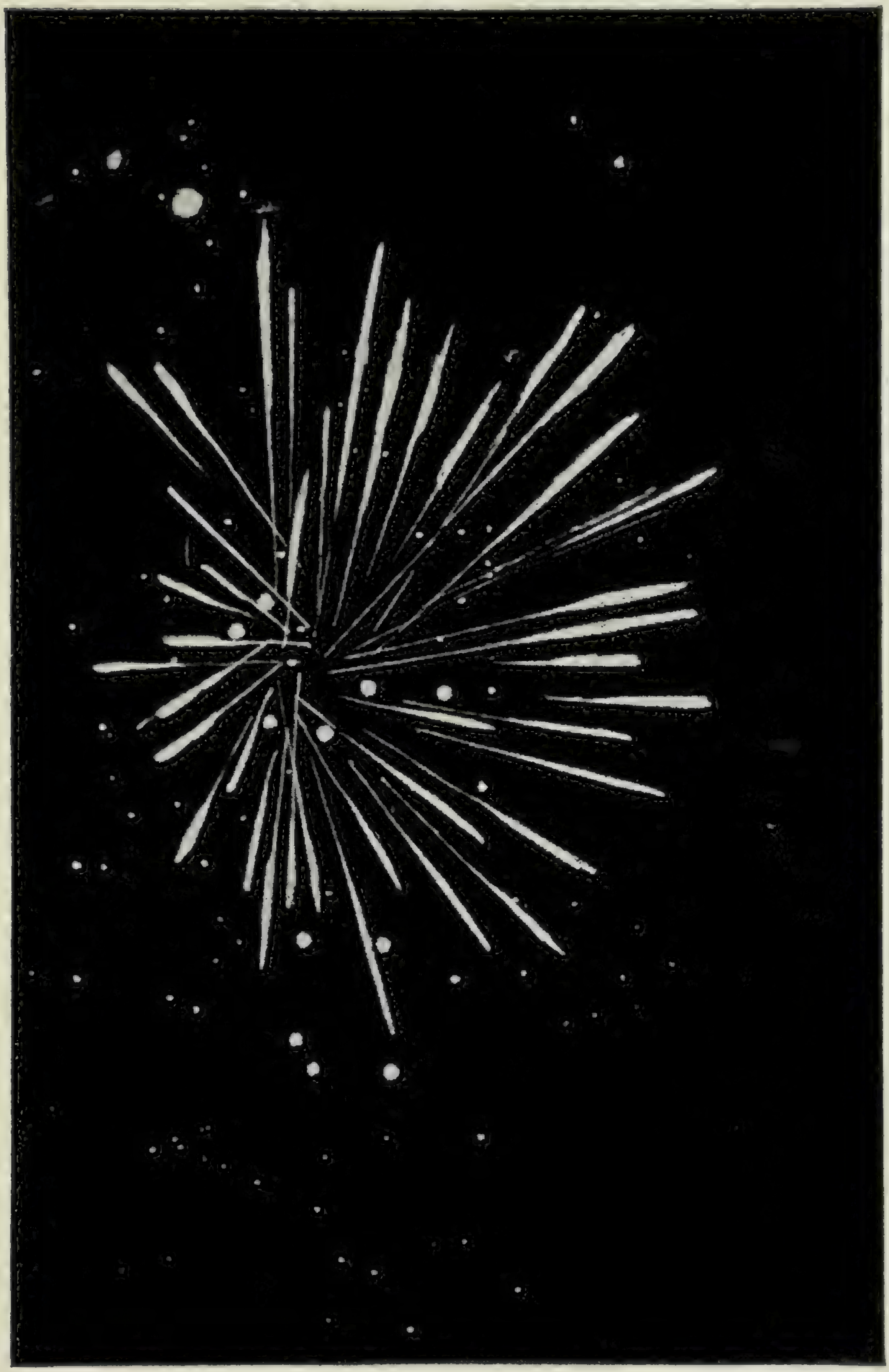
E. **MINOR STUDY**: Comets and meteors have always excited wonder and fear and have led to many superstitions.

Comets have always appealed to the superstitious elements in man. Dreadful events were always connected with the appearance of a comet. One poet expressed this belief as follows:

> *"When beggars die there are no comets seen,*
> *The heavens themselves blaze forth the death of Princes."*

When Halley's comet appeared in 1910, many people predicted that it would bring the world to an end. This comet is a visitor to our solar system every seventy-six years and its appearances have been recorded for many centuries.

Frequently, we see what are popularly called 'shooting stars'. The name is an unfortunate one. These meteors are not stars but bodies which enter the earth's atmosphere, where they become intensely hot due to friction when passing through the air. Most are consumed by this heat before they reach the earth's surface. A few fall to the ground and are



From "Through My Telescope" by W. T. Hay (Dutton.)

Fig. 268. Notice that this meteoric shower appears to radiate from a point.

called 'meteorites'. While most meteors are about the size of a small seed, occasionally there are much larger ones. A large meteorite in South Africa weighs about fifty tons. Some meteorites contain iron and nickel; others are mainly or altogether stone. The origin of meteors is in dispute.

Observation of meteors.

During the first half of the year, an observer should be able to see an average of about seven meteors an hour on clear moonless nights. About double this number may be expected on suitable nights during the remainder of the year.

The following important meteoric showers occur during the school year: the *Orionids*, which appear to radiate from the northern side of the constellation Leo, about November, 14-16; the *Geminids*, which seem to radiate from the constellation Gemini (the Twins), about December 10-13; the *Lyrids*, from the constellation Lyra, about April 21.

Bring in a report on any meteors you observe, giving the time and number.

F. MINOR STUDY: The stars are immense suns outside the solar system.

Now we shall give our attention to the stars, which, for a reason you will learn later, are described as fixed. They are outside the solar system.

PROBLEM I: How are the stars grouped as constellations?

Observation of the Great Dipper.

(i) *At different times on the same night.*

Early on a clear moonless night find the seven stars which form the Great Dipper. Locate the 'bowl' and the 'handle'. Nail a ruler or straight stick to the side of a post. Then turn this pointer until it is in line with one of the stars in the Great Dipper. Make a drawing of the group of stars and on it note the one towards which the ruler is directed. Notice the time.

Two hours later see if your ruler still points to the star. Make another drawing of the Dipper on the paper you used previously. Has the position of the group in the sky altered? Have the stars which make up the Dipper altered their relative positions? (In other words, has the shape changed?)

If possible, make a third observation and sketch on the same night.

The Great Dipper is part of the constellation (Lat. *con*, with or together; *stella*, star) or star-group known as Ursa Major or the Great Bear.

(ii) *At the same time on different nights.*

Choose a time in the evening at which it will be possible for you to make observations over a fairly long period. Bring the ruler as accurately as possible into line with one of the stars in the Dipper. At the same time on a night one month later, look along the ruler. Is it sighted on the star? Again direct the rod in the direction of the star. Repeat your observation at the same time at the end of another month. In what direction does the Great Dipper appear to move?

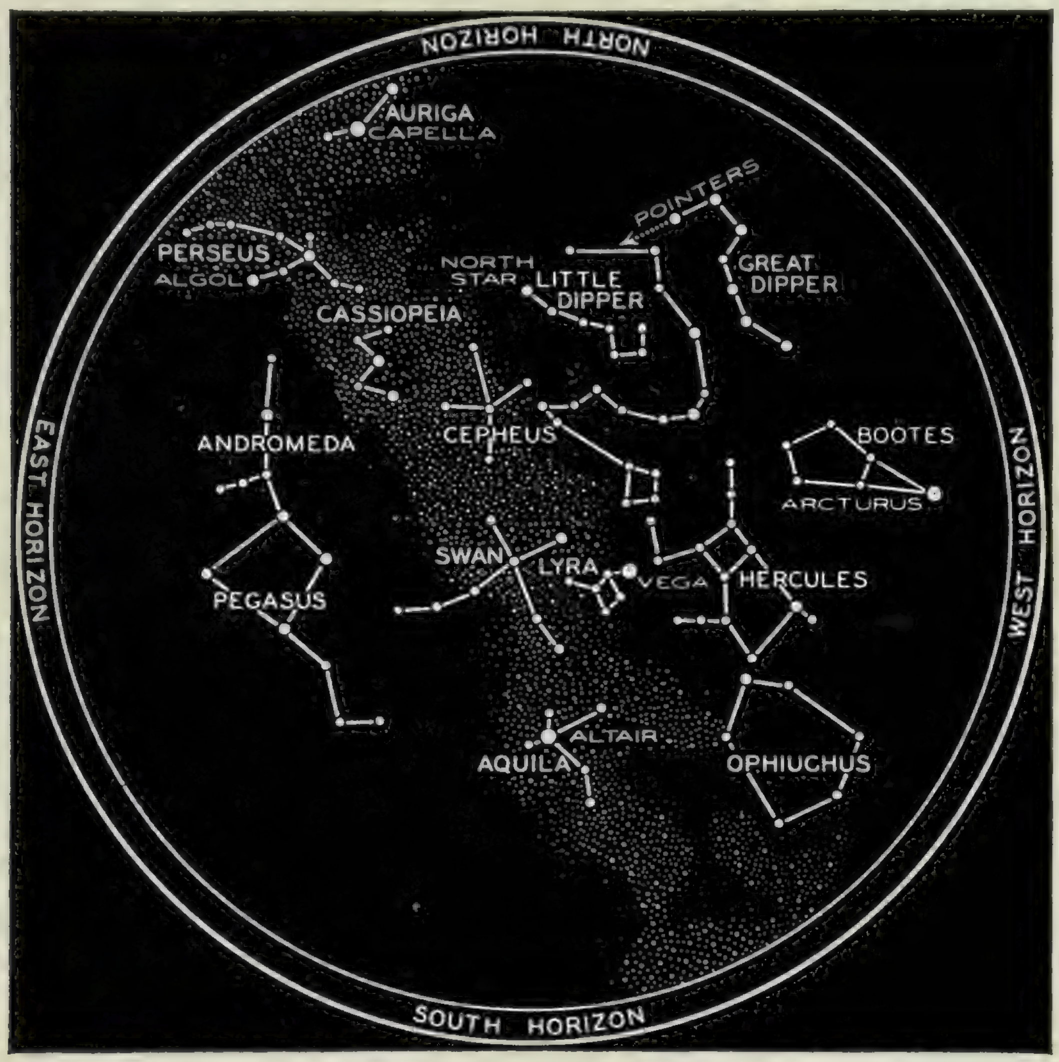


Fig. 269. The evening sky—Sept. 1, 9 p.m.; Sept. 15, 8 p.m. Sept. 30, 7 p.m.

Some other constellations.

Look at the two stars in the Great Dipper which make up the side of the bowl remote from the handle. Imagine that they are joined by a line and that this is produced to about five times its length in the direction of the open side of the bowl. Close to its end is the North Star. The two stars in the bowl of the Great Dipper are known as the 'pointers'.

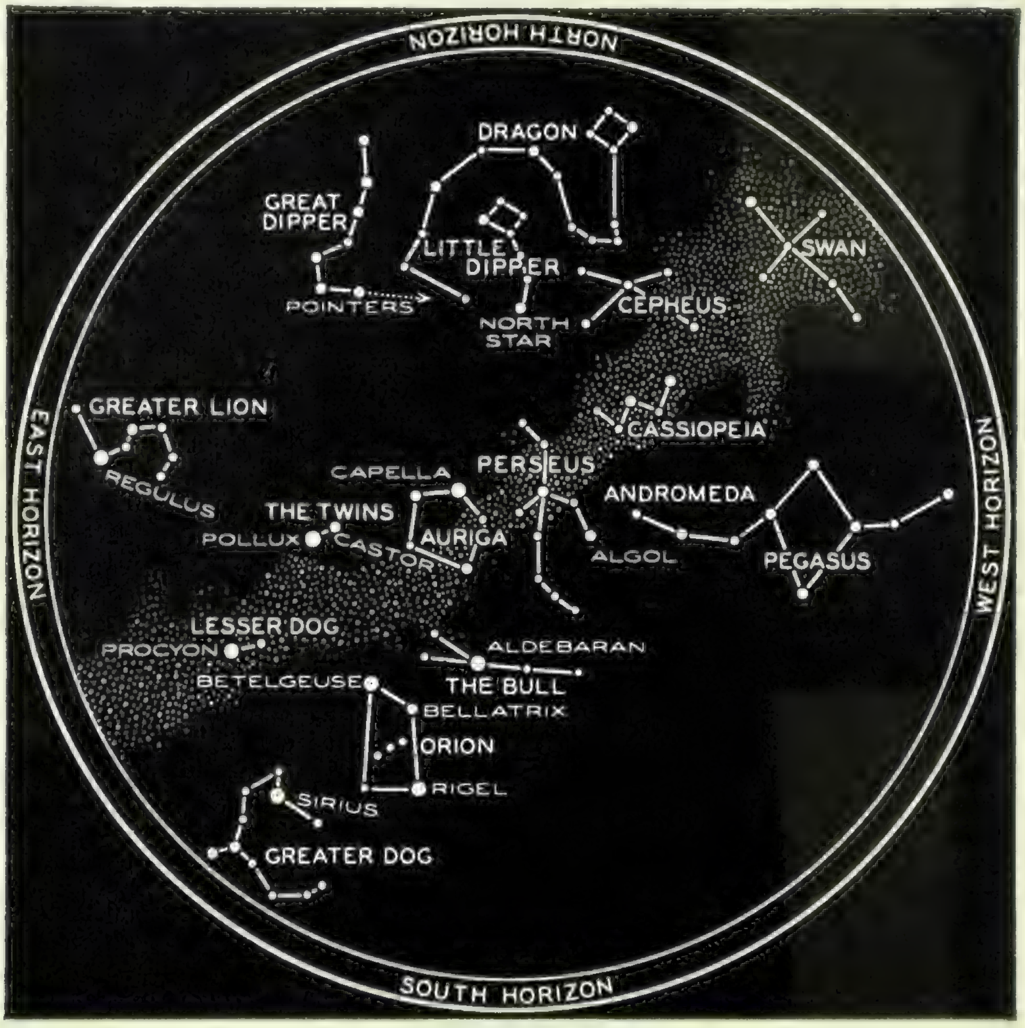


Fig. 270. The evening sky—Dec. 1, 11 p.m.; Dec. 15, 10 p.m.; Jan. 1, 9 p.m.; Jan. 16, 8 p.m.; Feb. 1, 7 p.m.

The North Star is at the end of the handle of the *Little Dipper*, in the constellation Ursa Minor or the Lesser Bear.

An imagined line from the star in the end of the Great Dipper's handle to the North Star will, when produced, pass near a group in the form of an irregular W. This is *Cassiopeia's Chair*.

Find the two stars on the inner side of the Great Dipper's bowl. These point towards the *Dragon* (Draco).

Imagine that the handle of the Great Dipper is extended. This will assist you in finding a very bright yellowish-red star called Arcturus in the constellation *Boötes*.

Find the two stars which with the 'pointers' make up the Great Dipper's bowl. Imagine a line drawn through these stars and produced about twelve times its length. This will guide you to the brilliant star Vega in the constellation *Lyra*. (Fig. 269.)

If you follow a produced imaginary line through the 'pointers' to the North Star you will find the Great Square in the constellation *Pegasus*.

In December you will have no trouble in finding the splendid constellation *Orion*. Make yourself familiar with the constellation on the star map; note particularly, as an aid to recognition, the three stars in the centre. (Fig. 270.)

In addition to observing the Great Dipper, each member of the class should note the position of some other constellation at the same hour on nights separated by intervals of a month. The results should be combined.

Observations on the North Star.

Rotate a stick nailed to a post until it points directly at the North Star. Find if it is still directed towards the star at the end of an hour. Is it accurately sighted on the star at the same hour on a night three weeks later?

Some of the more brilliant fixed stars.[1]

Already you are familiar with the North Star,[2] and the much brighter *Arcturus* and *Vega*. With the aid of your star maps, locate *Capella* in the constellation Auriga, and *Betelgeuse*, *Rigel*, and *Bellatrix*, all in Orion.

Follow the imaginary line through the three stars in Orion to which we have referred and find the brilliant *Sirius*, or the Dog Star, in the constellation Canis Major or the Greater Dog. Bellatrix and Betelgeuse will guide you to *Procyon* in the Lesser Dog, Sirius and Bellatrix to the red *Aldebaran* in the Bull. Rigel and Betelgeuse point to the heavenly Twins, *Castor* and *Pollux*. (The Latin for 'twins' is 'gemini'. Some very small boys keep up an old Roman custom of referring to the Twins when vigour of speech was thought necessary.) Aldebaran and Pollux will guide you to *Regulus* in the constellation Greater Lion.

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[1] Optional.

[2] It may prove convenient to have a list of the other names by which these stars are known: North Star (Pole Star, Polaris, α Ursae Minoris); Arcturus (α Boötis); Vega (α Lyrae); Capella (a Aurigae); Sirius (Dog Star, α Canis Majoris); Betelgeuse (α Orionis); Rigel (β Orionis); Procyon (α Canis Minoris); Aldebaran (α Tauri).

The letters α and β, the Greek a and b, are pronounced 'alpha' and 'beta' respectively. Astronomers use them to distinguish stars in the same constellation, e.g. α Orionis (alpha of Orion) β Orionis (beta of Orion.)

[3] The reddish Betelgeuse is farther north than the bluish-white Rigel.

PROBLEM II: **What is the size of the fixed stars and what are their distances from the earth?**

We have learned that the earth is but one of a number of worlds moving around a great spherical furnace. We have strained our imaginations in attempting to grasp the vastness of the solar system and our notions of man's importance have shrunken. Yet we are only at the beginning.

Of the nine planets, Venus approaches nearest to us. The least distance is some 26,000,000 miles. Yet when we look for our nearest neighbour *outside* the solar system, we have to travel in imagination 25,000,000,000,000 miles! This is 272,000 times our distance from the sun. We were impressed when we learned that a ray of light required five and a half hours to travel from the sun to the most remote of the nine planets. A ray of light starting from the fixed star Alpha Centauri, one of our nearest neighbours outside the solar system, would travel for four and one-third years before it reached us. The North Star which is reasonably close to us, as stars go, is more than sixty times as far from us as Alpha Centauri.

These distances are, of course, quite unimaginable. Instead of using the mile as a unit of measurement, a vastly greater measuring stick is adopted, namely the distance light travels in a year. In one second light travels 186,000 miles. Therefore, in a year it would go 186,000 x 60 x 60 x 24 x 365¼, or about six million million miles. This distance is called a light year. The North Star is 272 light years distant from the earth, the sun, 8 light minutes. Use the light year as a unit of measurement instead of the mile does not help the imagination, but it does enable us to express great distances more conveniently and to compare one with another more easily. It may be of interest to learn how far from the earth are some of the other stars you have observed.

Star	Distance in light years	Star	Distance in light years
Arcturus	38	Betelgeuse	272
Vega	26	Rigel	543
Capella	48	Procyon	10
Sirius	9	Aldebaran	57

If Betelegeuse had vanished from the heavens in the year 1759, we would not learn of the fact until 2031. Can you explain this statement?

In imagination let us place ourselves on Vega. Even with the aid of the most powerful telescope, nothing of our solar colony would be visible except the sun, and it would appear as a point of light, a star like billions of others. From even the nearest star the planets could not be seen.

What then are the fixed stars? Astronomers tell us that they too are suns and that many are immensely bigger than ours. Arcturus has a diameter thirty-five times that of the sun. Betelegeuse, one of the giants, has a volume twenty-seven million times that of the sun and brightness one thousand times greater. If we represent Antares by a globe of diameter 2½ feet, on the same scale the sun would have the diameter of a pin head. Our sun may be regarded as a medium-sized star. Whether or not there are planets other than those in the solar system we have no means of telling. A man clinging to a raft in mid-ocean is not more alone than the solar system in the universe.

PROBLEM III: How can we explain the apparent daily movement of the stars?

Observation of the stars at different times on the same evening shows that all except the North Star[1] alter their position. The general pattern remains the same; the stars which make up Cassiopeia's Chair, the Great Dipper or other group do not alter their position with respect to one another. They appear to move as a whole.

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[1] In reality the North Star also moves, but this cannot be detected by the unaided eye.

A model which may help you to understand the apparent movement of the stars.

Thrust a knitting needle through the centre of an orange. Support needle and orange by using a flower pot (Fig. 271) or other convenient means. On a piece of white cardboard mark the Little Dipper, the Great Dipper and Cassiopeia's Chair in their approximate relative positions. The North Star should be in the centre. Pass the end of the needle through the cardboard at the place where the North Star is marked. Imagine that the orange is the earth, that the cardboard is the evening sky, and that you are standing on the one and looking up at the other. Keeping the 'sky' stationary, rotate the earth from west to east. How would the stars appear to move if the observer were unconscious of the earth's motion? Which star would remain fixed? Would the apparently moving stars alter their position with respect to one another? (As we have indicated, the earth's imaginary axis if produced far enough would pass close to the North Star. In what position would an observer at the North Pole see the star?)

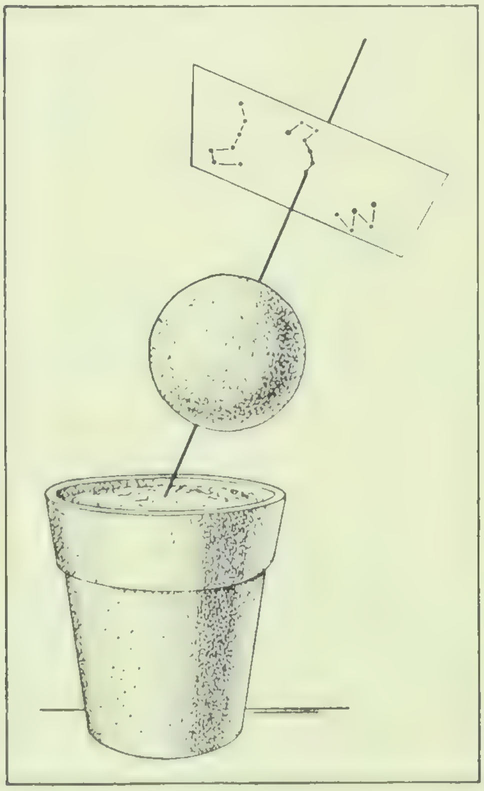

Fig. 271. This model may assist you in understanding the apparent movement of the stars.

How to obtain star trails.

Point a rigidly mounted camera towards the North Star on a calm, cloudless night, and expose the film from 9 p.m. to 3 a.m. What evidence of the apparent motion of the stars is provided by the photograph?

The movement of the stars noted when observations are made at different hours on the same night is only apparent. Like the apparent daily journey of the sun from east to west, it is due to the earth's rotation on its axis.

The stars which are far above the horizon never rise or set, but in each 23 hourse and 56 minutes describe concentric, circles with the North Star as centre. Those distant from the North Star also describe circles with the same centre but the radius is so great that they disappear below the horizon, (Fig. 272). Like the sun and moon, they rise in an easterly and set in a westerly direction.

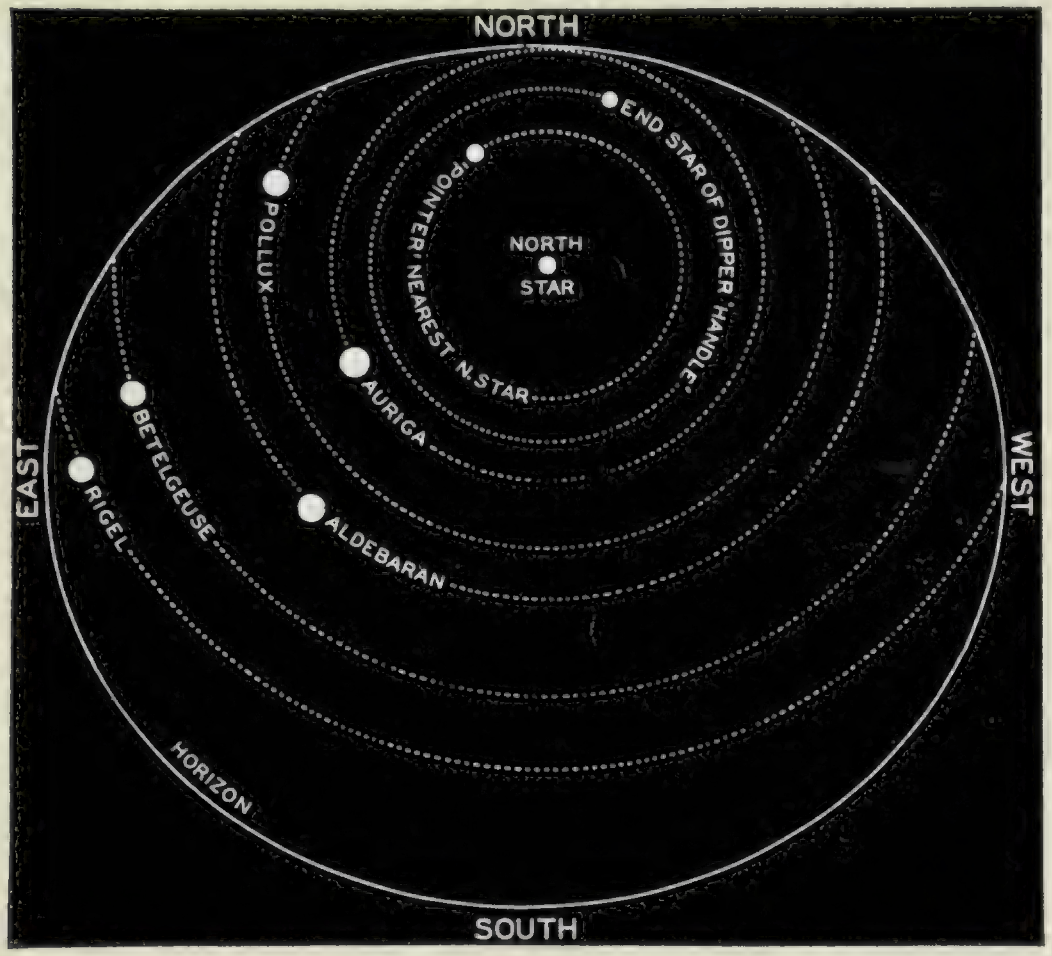

Fig. 272. Some stars rise and set; others do not.

PROBLEM IV: How can we explain the apparent annual motion of the stars?

When we note the position of the Great Dipper at the same hour on nights at intervals of three or four weeks, we find that there is a gradual change. The constellation appears to be making a very slow journey around the North Star in the same direction as that of the apparent daily movement.

If, at the same hour on different nights, we make observations on a star situated originally near the eastern horizon, we find that its position is farther and farther west until, at the end of six months, it disappears. About a month later, it may be found before dawn on the eastern horizon once more. A year would pass by before the star was seen at its original position at the time chosen.

The changes in position take place, of course, during daytime as well as at night. Because of the light of the sun, we are unable to see the stars until after sunset. We have pointed out that the daily movement of the stars is apparent and due to the rotation of the earth, on its axis. This more gradual motion in the same direction, is also apparent and is the result of the earth's annual revolution around the sun.

It may be asked why this second apparent motion cannot be noticed at successive hours in the same night. The reason is that the change is too slight. Due to the two motions, the apparent daily movement is complete in 23 hours and 56 minutes. In other words, each day a star is at the same point of its daily track four minutes earlier than on the day previous. At the end of a month, the difference amounts to 30 x 4 minutes or 2 hours. Hence, the alteration due to the annual movement is obvious to the unaided eye after a reasonable interval. Stars that rise or set do so 2 hours earlier every month.

Because of the fact that the stars maintain their positions with respect to each other, they are said to be 'fixed'. Strictly speaking, they are not fixed at all but have real motions and great velocities.

These real movements cannot be seen by the naked eye because of the vast distances which separate us from the stars. If a shepherd familiar with the sky 5,000 years ago were to see it in the twentieth century, he would notice no change!

PROBLEM V: Where is the milky way?

Observe the great band of cloudy light passing through the constellations Cassiopeia and Perseus. This is known as the Milky Way. Many other names such as the Path of Souls and the Sky River have also been applied to it.

The telescope shows that the Milky Way contains millions of suns at such enormous distances from us that their light blends.

G. MINOR STUDY: Shadows are formed because light travels in straight lines through one substance.

An important property of light.

When we spoke of light travelling at 186,000 miles per second from the sun to the earth, we assumed that it made no 'side trips', but came by the shortest route. It is not difficult to show in the classroom that, when passing through a medium which is uniform throughout, light travels in a straight line.

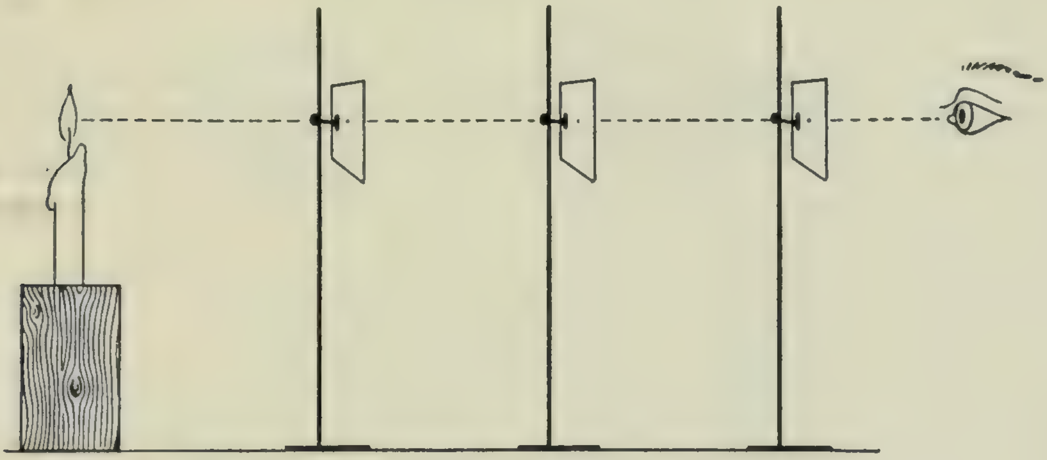

Fig. 273.

Light travels in straight lines when passing through one substance.

Pierce each of three pieces of cardboard with a small hole. Place the screens so that they are between the eye and a candle flame, (Fig. 273). Adjust the positions of the two nearest the flame so that the light may be seen through the opening of the third.

Are the three holes in the same straight line? (In this experiment the light passed through one substance, namely air. Later we shall learn about the path of light when passing from one substance to another).

Of what property of light do we take advantage when placing a number of posts in line or when aiming with a rifle?

PROBLEM I: How are shadows formed?

As everyone knows, a shadow is produced when an object which is not perfectly transparent is placed in the path of a beam of light.

An experiment in which we learn about shadows.

In a room without light other than that furnished by a lamp, set up the apparatus shown in Fig. 274. Suspend the golf ball or other small sphere three or four feet from the lamp. Move the cardboard screen XY close to the ball and notice the character of the shadow.

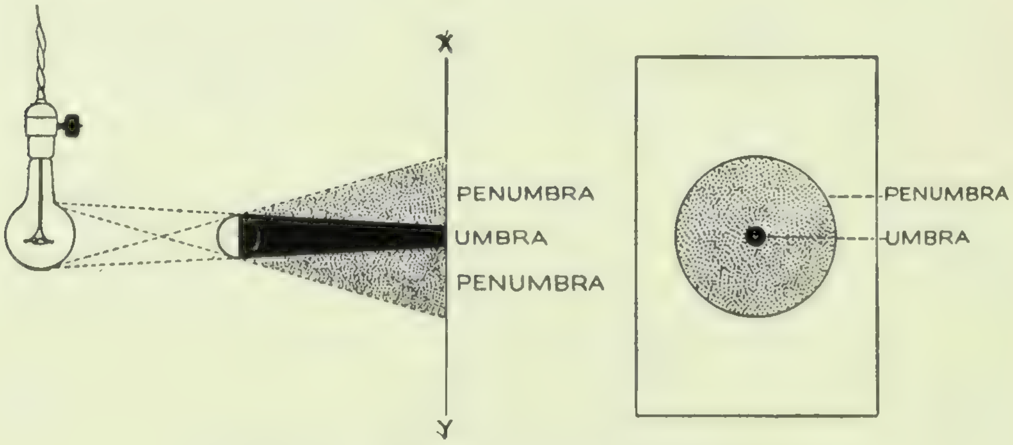

Fig. 274. How shadows are produced.

Where is the darkest portion of the shadow? This part is called the umbra. The less intense shadow surrounding the umbra is known as the penumbra, (Lat. *paene*, almost; *umbra*, shade).

In the regions of both umbra and penumbra make small holes in the cardboard. Look through them in the direction of the lamp. Is the cardboard in the region of the umbra receiving any light? Is there any light reaching the screen in the region of the penumbra?

Move the screen slowly away from the sphere. Observe and describe the changes that take place in the umbra and penumbra.

Why are the shadows longer in the early morning and evening than in the middle of the day? Illustrate your answer by diagrams.

PROBLEM II: How can we explain eclipses of the sun?

In early days, eclipses of the sun and moon were regarded as warnings from the angry gods, signs that some terrible danger was about to happen to the people. While we are impressed with these phenomena, as we are with dawn, sunset, thunder, lightning and other happenings in nature, we are not terror-stricken.

When the sun, moon and earth come into line with each other in the order named, the shadow of the moon is cast on the earth. Observers in the umbra of this shadow, a patch about a hundred miles in diameter, cannot see the face of the sun. An eclipse of this kind is said to be total. Surrounding this area is the region of penumbra in which the eclipse is described as partial, because the sun is not entirely obscured. Due to the earth's rotation on its axis, its revolution around the sun, and the moon's movement in its orbit, the umbra moves over the surface of the earth forming a band about 100 miles wide. The time re-

Fig. 275. An eclipse of the sun. The narrow end of the moon's umbra traces the path of totality. In the region of the moon's penumbra a partial eclipse will be observed. Draw a diagram showing how the umbra and penumbra of the moon, and also of the earth, were obtained.

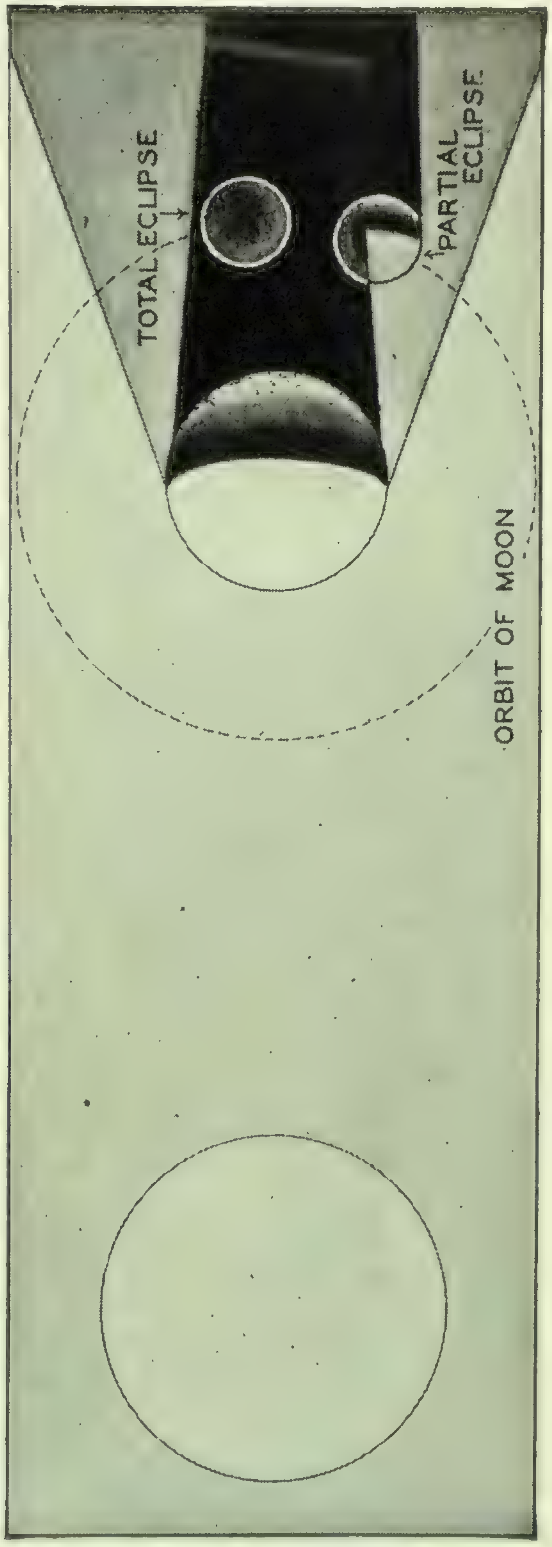

Fig. 276. How eclipses of the moon are caused.

quired for the umbra to pass any point varies from a few seconds to a maximum time of $7\frac{1}{2}$ minutes.

PROBLEM III: Can we explain eclipses of the moon?

When it comes between the sun and moon, the earth may cast a shadow on its small companion. While the moon is passing through the umbra, the eclipse is total. When it is in the penumbra, the decrease in brightness is so slight that we do not call it an eclipse. However, when the moon is partly in umbra and partly in penumbra, a portion of its face is obscured and the eclipse is partial.

Solar eclipses can occur only at the time of new moon, and lunar eclipses when the moon is full. Why? (See p. 386.) They do not occur at every new or full moon because the planes of the orbits of the earth and moon do not quite coincide. In other words, if you imagine two flat surfaces on one of which lies the path of the earth around the sun, and on the other, the path of the moon around the earth, these surfaces are inclined to each other at a small angle.

H. MINOR STUDY: Luminous and non-luminous heavenly bodies.

Luminous and non-luminous objects.

In a dark room, a piece of cold metal is invisible because it gives off no light; but, if we heat it sufficiently, it glows. We say that the hot metal is luminous. No light is given out by the filament in an unattached electric light bulb; it is non-luminous. But, if we screw the bulb into a socket and switch on the current, the wire becomes hot and gives us light. From your own experience you will be able to give a number of examples of luminous and non-luminous bodies.

It is impossible for us to see an object unless light comes from it to our eyes. Why, then, are we able to see non-luminous bodies? When we enter a perfectly dark room, everything is invisible. Then we provide ourselves with a luminous body by striking a match. Light from the match falls on a non-luminous chair, and the chair sends back this borrowed light to our eyes to the great relief of our shins.

This 'sending back' or reflection of borrowed light is clearly of the greatest importance. It is worth a little study.

PROBLEM I: How is light reflected?

When we hold an object in front of a mirror, a piece of plate glass or other very smooth surface we see, apparently behind the surface, what is called an image. We know, however, that nothing is there. We can see an object or an image only when light travels from it to our eyes. Hence, when we use a mirror, the light must go from the object to the mirror and back to the eyes. Along what path does the light travel when making this roundabout journey?

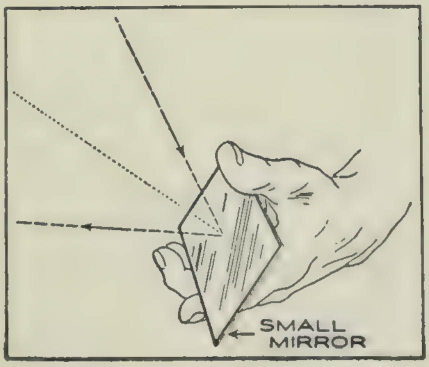

Fig. 277. Sunlight reflected from a mirror.

When you throw a ball directly at a smooth wall, in other words, in a direction perpendicular to the surface, it bounces back along the same line. When you throw the ball at an angle at the wall, it bounces off at an angle. Light is reflected from surfaces in the same way, (Fig. 277).

If there were no reflection of light, you could not read this page; you could not see your own hand even when you held it close to your eyes. Nothing would be visible except luminous objects like the sun, a red-hot poker or a neon sign.

Regular and irregular reflection.

If parallel rays of light were to fall on a perfectly smooth surface, all of the reflected rays would be parellel. Such reflection is described as regular, (Fig. 278). When the surface is rough, the reflected rays have a great variety of directions and the reflection is said to be irregular, (Fig. 278). Frequently, light which is irregularly reflected is spoken of as diffused.

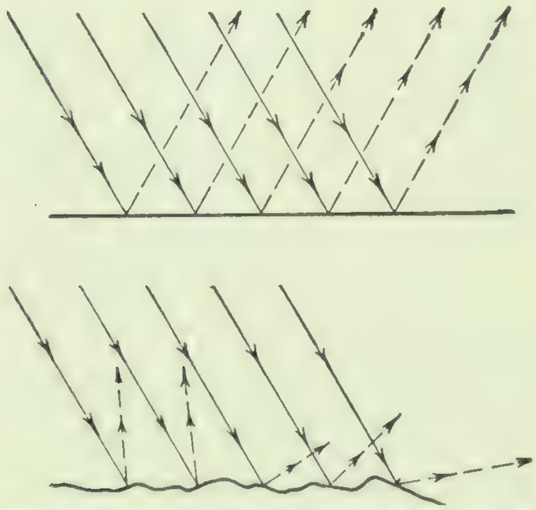

Fig. 278. Regular reflection from a smooth surface, and irregular reflection from a rough one.

Sometimes we do our utmost to procure regular reflection. We polish our shoes and the bodies of our cars; we buy tables with highly-finished tops. Often we dislike regular reflection. How unpleasant is the more or less regularly reflected light from pictures, blackboards, glazed paper, smooth roads and shiny noses!

The glare which results from direct lighting is harmful to the eyes. In our homes and schools we are recommended to use diffused light, that is to say, light reflected to us from a multitude of surfaces. You will recall the difference in reading when the page is illuminated by direct sunlight and when it is lighted by the diffused light received through a north window. In the latter case, the light is reflected to the page from the clouds and from countless other surfaces. The walls of a room should not be white, which may produce glare, or dark, which would cause absorption and waste of light; a cream-coloured wall is regarded as satisfactory.

Luminous and non-luminous heavenly bodies.

The millions of stars which shine in the sky are masses of gas at extremely high temperatures. Those which have a white or blue-white light are the hottest. Rigel, for instance, with a brilliance thirteen thousand times that of the sun, is an unimaginably hot star. The reddish Beteleguse, on the other hand, is much cooler. Intermediate in temperature between the blue-white and the red stars are those which emit yellow or orange light.

Not all stars are luminous; some are dark. We become aware of their presence when they cut off the light from a luminous star.

None of the planets or their moons is luminous. The light they send to us is irregularly reflected, or diffused sunlight. Our own planet shines as brightly in the sky as any of the others, but, like these others, it is merely reflecting sunlight.

You are aware, no doubt, that when a coin is rubbed on a board it becomes hot. Similarly, when meteors enter the layer of air around the earth, they become intensely hot, and hence, luminous, because of friction with the gases of the atmosphere.

PROBLEM II: How are the phases of the moon explained?

We have observed that in a period of about 29½ days the appearance of the moon underwent a series of changes. These changes are known as phases. As everyone knows, there is no alteration in the size of the moon, but merely of the amount that we can see of its illuminated face.

An illustration of how the phases of the moon are caused.

At night, hold a ball at arm's length in front of a lamp and stand so that the ball is directly between you and the light. If you imagine that the lamp is the sun, that the ball is the moon, and that you are the earth, you will understand why no light reaches the earth from a new moon.

Still holding the ball at arm's length, turn slightly on your heel. Notice that a small fraction of the illuminated half of the ball is now visible. Try to see the shape of this bright portion. It represents the slender crescent of the young moon.

As you turn little by little, observe that the crescent is growing or waxing. Soon, half of the illuminated hemisphere is visible. This represents the appearance of the moon when seven days old. It is now at its first quarter.

After a half revolution, how much of the lighted part of the ball can be seen? How is the moon described at this stage? How old is it?

As you continue to turn, observe the change in the size of the visible lighted surface. When the same changes occur in the moon, we say that it is waning. Pause when you have made three-quarters of a turn. The illuminated part of the ball visible to you represents the moon at its third quarter. What is its age?

As you approach the position from which you started, observe the diminished size of the crescent.

Do the horns of a crescent moon point towards or away from the sun?

A dim outline of the dark part of the disc may be seen when the moon is young. This is commonly described as "the old moon in the arms of the new." We are enabled to see this dark portion because light from the illuminated part of the earth's surface reaches the moon and is reflected from the surface of the latter to our eyes. In other words we see it by means of reflected earthlight.

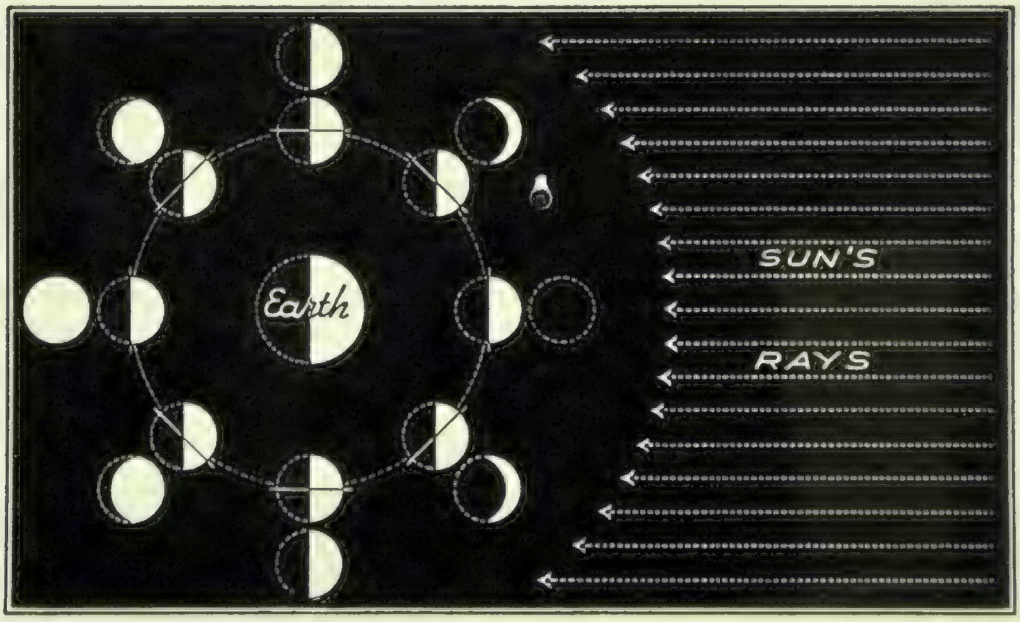

Fig. 279. The phases of the moon. In the inner circle is shown the moon as it might be seen in its different positions from the sun. In the outer circle, the moon is shown as it is seen from the earth.

(1) Why are we unable to see the young moon rising?

(2) Explain why the horns of a crescent moon are not turned towards the horizon.

(3) Sometimes we see drawings of a crescent moon with a star between the horns. Can this condition occur in nature? Give a reason for your answer.

I. MINOR STUDY: The heavens tell us where we are on the surface of the earth.

Longitude and latitude.

At a time when the known world centred around the Mediterranean Sea, men devised a method of dividing the maps of the world into small oblongs by means of lines. Those lines which measured its length were called lines of longitude, while those which measured its width were called lines of latitude. Since the length of the Mediterranean was from east to west, longitude is distance east and west around the earth; while latitude is distance north or south of the equator.

A circle has 360 degrees. A line drawn round the earth through the poles is a circle. A quarter of this circle is 90 degrees. Latitude is measured by degrees. The starting point at the equator is called 0 degrees, while the farthest points, 90 degrees, are at the poles. The width of 1 degree on the earth's surface is taken as 69 miles. (25,000 ÷ 300 = 69).

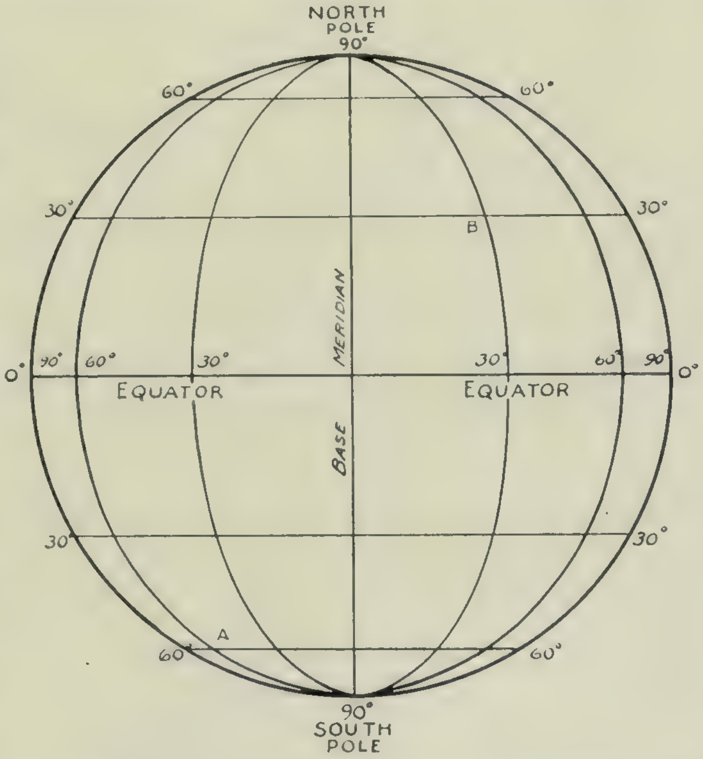

Fig. 280. This shows how meridians of longitude and parallels of latitude are arranged on a map. The letter A is at 60° south latitude and 60° west longitude. Where is B located?

Since the earth's geographic pole points in the direction of the North Star, a simple way to find the latitude of any locality is to find the elevation of the North Star above the horizon.

A method of finding the latitude.

In a north-south direction, and about 12 feet apart, drive two stakes into the ground. Place a scantling on these stakes and by using a builder's level, adjust the stakes until the scantling is level. Tack a board about 12 feet long to the south end of the scantling, and, by means of a board nailed to this one at the north end, raise that end until a student with his eye at the south end sights the North Star along the board. Measure the angle between the scantling and the top of the board using a protractor; this angle measured in degrees is the observer's latitude. Sailors find latitude by finding the elevation above the horizon of various heavenly bodies.

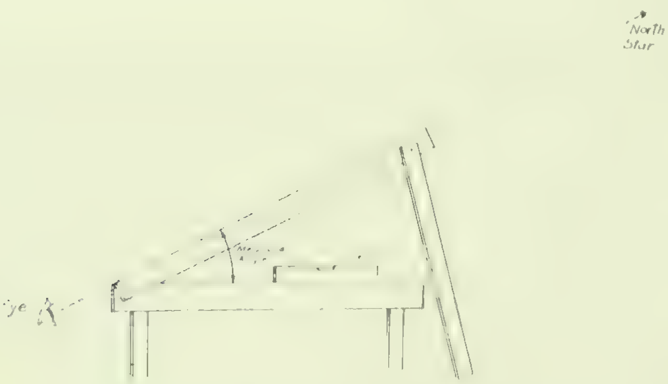

Fig. 281. How to find your latitude.

In measuring longitude, the observatory of Greenwich, near London, England, is taken as a starting point. The line on a map which runs through Greenwich is called Zero Meridian and from it east and west longitude are measured (180 degrees in each direction).

Since the earth rotates on its axis once every 24 hours from west to east, people living east of us see the sun rise before we do. To be able to have our day correspond with sun time, man has divided the earth into belts or zones. The first zone boundaries are $7\frac{1}{2}$ degrees on each side of the zero meridian. Since 360 ÷ 24 = 15, 15 degrees of longitude correspond to one hour. New zone boundaries are found each 15 degrees east and west of the first zone boundaries.

In Canada, under this system, we have five time belts, (six if you include the Yukon territory). Fig. 282 shows the boundaries for these time belts. The 180th meridian is called the International Date Line. To keep the calendar right as we go west around the world, a day must be added; when an eastbound ship crosses this line, a day is subtracted.

Sailors locate their longitude by noting the passing of a

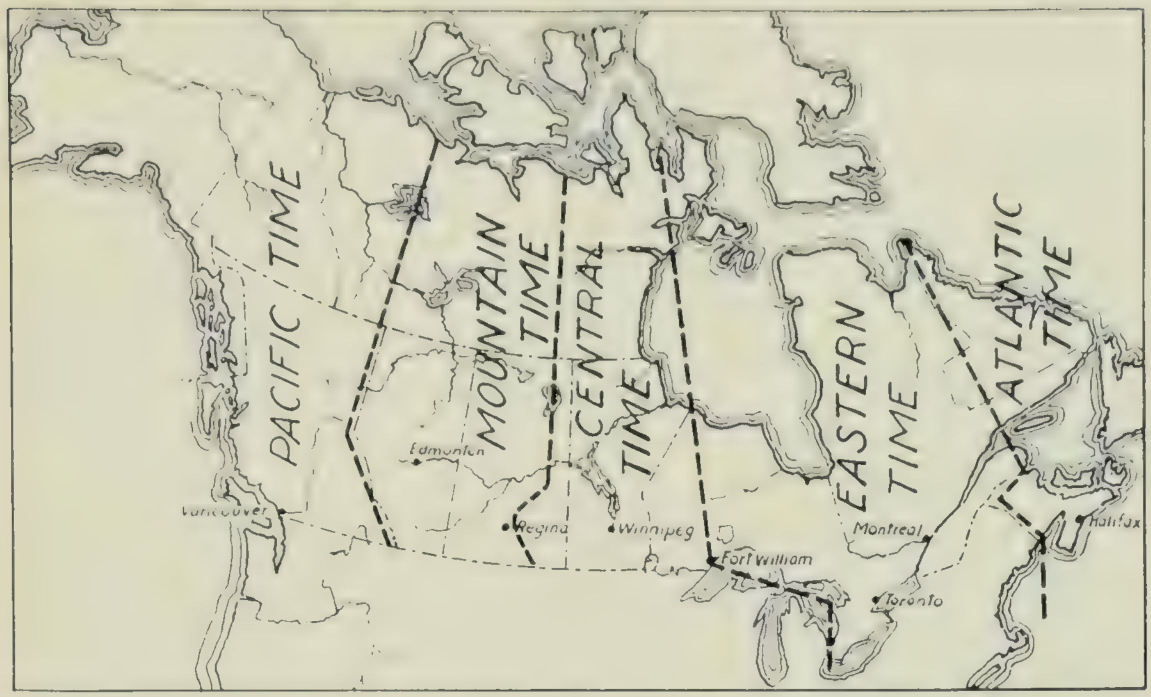

Fig. 282. The time belts in Canada.

heavenly body through the meridian directly overhead. If you could stand directly under a north-south opening in the roof of a barn or shed and notice the time when a certain star passes the opening, you could find your longitude from the Nautical Almanac, a book that gives the time when each bright star is on the zero meridian. Find the difference in time, make use of the fact that one hour corresponds to 15 degrees, and you will have your longitude.

Note: Meridians of longitude are not parallel, but come to a point at each pole.

APPENDIX

ELEMENTARY MEASUREMENTS.

Importance of measurement in everyday life.

For a moment or two let us consider the many needs for measurement in everyday life. Frequently, people boil eggs for four minutes, are paid by the hour, are given a two-week holiday or a year in the penitentiary; these of course, involve the measurement of time.

When we refer modestly to our height, when we buy ribbon, window panes and weather-stripping, or again, when we inform the stranded motorist of the distance to the nearest garage, we are concerned with the measurement of length.

Wall board is sold by the square foot, linoleum by the square yard and land by the acre. These transactions demand a knowledge of the amount of area.

Milk is bought by the quart, gasoline by the gallon, and wheat by the bushel. In each case, bulk or volume must be measured.

Measurements of mass are necessary when we purchase butter, meat, tea, sugar, coal and a host of other commodities.

Units.

When we say that a man is six feet tall, we imply that there is a *unit* of length, the foot, and that six of these units make up his height. Before we can state the size of a farm, we must have in mind a unit of area, the acre. Indeed, all statements of quantity include two ideas (a) the unit, (b) the number of times the unit is taken.

What is the origin of these units? Formerly, a number of units were based on parts of the body. There were the length of a foot, the length of a pace, a span, and so on. It is clear that these were unsatisfactory units because they varied from person to person. One of the great difficulties of international trade to-day is the variation in money units. Overnight, the value of the monetary unit may change and importers and exporters are in a state of uncertainty about what they must pay or what they shall receive for their goods.

Fortunately, our units, other than those of money, are now fixed by legislation. In the Standards Office in London is kept a bronze bar with a gold plug or stud near each end. In each stud is a fine line. The distance between these lines is defined as the Imperial Yard. Copies of this standard yard have been made, and one is kept at Ottawa. From this yard are obtained the *derived* units, the mile, rod, foot and inch. Similarly, there are the Imperial Pound, the Imperial Gallon and their copies.

There are certain disadvantages, familiar to every schoolboy and schoolgirl, in the British system of measurement. A more convenient system, now used by English-speaking peoples for scientific purposes, and by the rest of the civilized world for all measurements, was established by France. It is known as the metric system.

The metric system.

The original metre, a unit of length approximately equal to 39⅓ inches, was obtained in 1799 by taking the one ten-millionth part of that portion of the meridian through Paris which lies between the Equator and the North Pole. Later, it was discovered that the measurement was slightly in error. However, the International Standard Metre used today is a close copy of the original. The actual bar, kept at Sèvres near Paris, is an alloy of the very durable metals, platinum and iridium, and the metre is defined as the length between two marks on it. Close copies of the Standard Metre are possessed by a number of countries.

From the metre are derived a number of larger and smaller metric units of length such as the kilometre (one thousand metres) and the centimetre (one hundredth of a metre).

A little rectangular box, the sides of which are each one centimetre long, has a bulk or volume of one cubic centimetre. One thousand of these boxes would make up the metric unit of volume, the litre.

A cylinder of platinum-iridium alloy, also carefully guarded in Sèvres, is defined as the International Kilogram. A number of copies, which do not differ from the International Kilogram by more than one part in a hundred million have been distributed to other countries.

Metric units of length.

Examine a metre rule. Compare roughly the metre and the yard. There are a thousand metres in the kilometre, a unit which replaces the mile in France and many other countries. What fraction of a mile is a kilometre?

Notice the length of the first subdivision of the metre, the decimetre. How many decimetres are there in one metre?

The next subdivision is the centimetre, a unit much used in science. How many centimetres make up (a) a decimetre, (b) a metre?

Into how many parts is each centimetre divided? These are called millimetres. How many millimetres does a metre contain?

What advantages over the yard and its subdivisions do the metre and its subdivisions possess? Have they any disadvantages?

MEASUREMENT OF A STRAIGHT LINE.

Precautions necessary in measuring a straight line.

It may seem to some pupils that learning to measure a straight line is a very petty matter. Yet, the writer remembers a professor of civil engineering who used to say facetiously that he required a year to teach freshmen how to draw one!

Draw a straight line and along it place a scale. Note the reading at each end when your head is (a) slightly to the left of it, (b) slightly

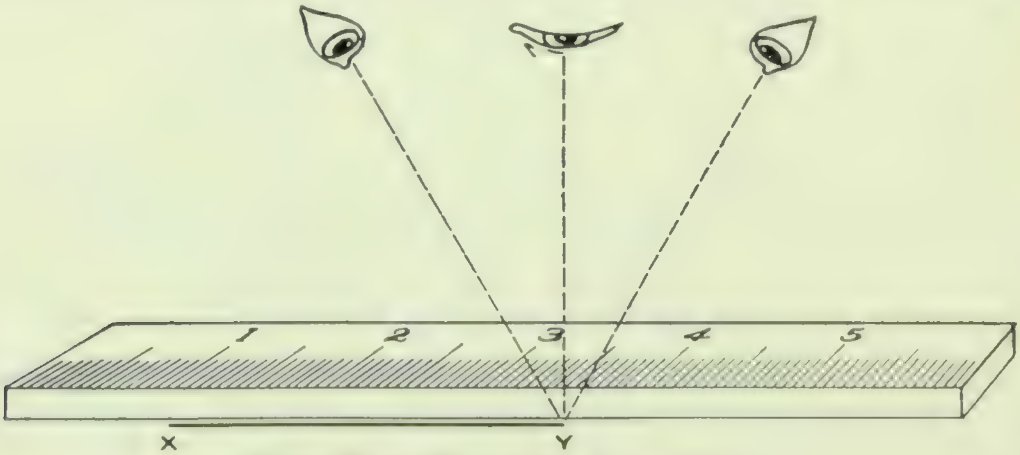

Fig. 283. Error due to parallax.

to the right of it, and (c) directly above it. (Fig. 283.) The apparent displacement in the end of the line as the head is moved is called parallax.

Describe a method of avoiding the error due to parallax.

Another aid in avoiding this error is the use of a scale with a bevel; this makes it possible to bring the graduations close to the line.

Examine a ruler on which the graduations begin at the very end. Explain why continued use will impair the accuracy of the scale. What precaution would you take if you were measuring a line with such a scale?

Avoiding the error due to parallax and the use of the worn end of the ruler, if the graduations extend to it, measure the same straight line carefully five or six times. The slight variation in your readings indicates that it is advisable to make a number of careful measurements and then find the average .

A pair of dividers may be used in measuring a straight line. The instrument is adjusted until a point rests on each end of the line. It is then transferred to the scale and the reading taken.

To find the number of centimetres in an inch.

The writer had just entered his High School for the first time when he was pounced upon and required to settle this matter. Six years later his initiation into College physics took the same form, although in the meantime there was no obvious change in the units. An experiment so popular should not be lost to posterity.

What objections may be raised to drawing a line just one inch long and measuring it several times? Would an error of one-tenth of an inch in measuring a line seven inches long be as important as the same error in the case of one an inch or two in length?

In your notebook draw nine or ten lines not less than six inches long. Measure each carefully three times and obtain the average. Complete a table such as the following:

Line	Length in inches	Length in centimetres	Number of centimetres in one inch
1			
ii			
Etc.			

Find the average of the values obtained in the last column. The accuracy of measurement will not warrant more than one place of decimals.

If you have learned how to draw graphs, plot one showing the relationship between centimetres and inches. Use the graph for converting inches to centimetres and centimetres to inches.

(A number of pupils may co-operate in the above experiment.)

The following is a more accurate procedure. Obtain two unwarped yardsticks graduated in both inches and centimetres. Lay them side by side so that the British and metric scales are in proximity. Note two places, as far apart as possible, where the graduations coincide. Record the distance in both systems and perform the calculation.

MEASUREMENTS OF AREA.

The area of a rectangular card.

Draw rectangles with the following lengths and widths; (i) 10 centimetres, 6 centimetres; (ii) 8 cms., 5 cms.; (iii) 7 cms., 6 cms.; (iv) 9 cms., 4 cms. Divide each into squares the sides of which are one centimetre long. Complete the following table.

Rectangle	Number of centimetres in length of rectangle	Number of centimetres in width of rectangle	Number of cms. in length x number of cms. in width	Number of squares with area 1 sq. cm.
i				
ii				
iii				
iv				

In the case of each rectangle compare the product in the fourth column with the number of squares of one centimetre side.

If you were given the length and width of a rectangle, how would you determine the area? Using one of the rectangles you have drawn, find how many square centimetres there are in a square inch.

MEASUREMENTS OF VOLUME.

The volume of a rectangular solid.

(i) Using cubes of one centimetre (or one inch) side, construct a rectangular solid of one tier, (Fig. 284).

How many cubes are along one side? How many are there along the other? From these two numbers calculate the number of blocks in the solid. What is the volume (a) of each block, (b) of the whole solid?

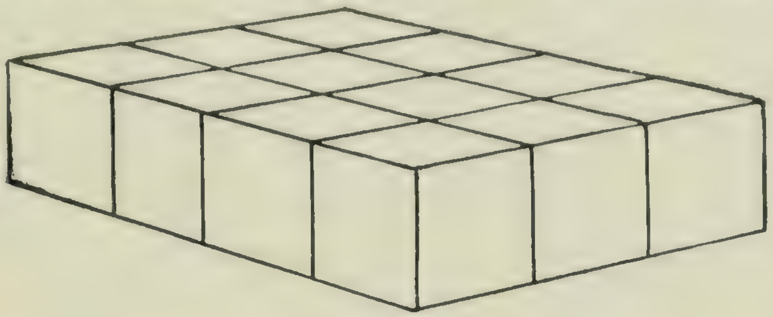

Fig. 284.

(ii) Using the cubes, construct a rectangular solid of a number of tiers, (Fig. 185). How would you find the volume (a) of one tier, (b) of the whole solid?

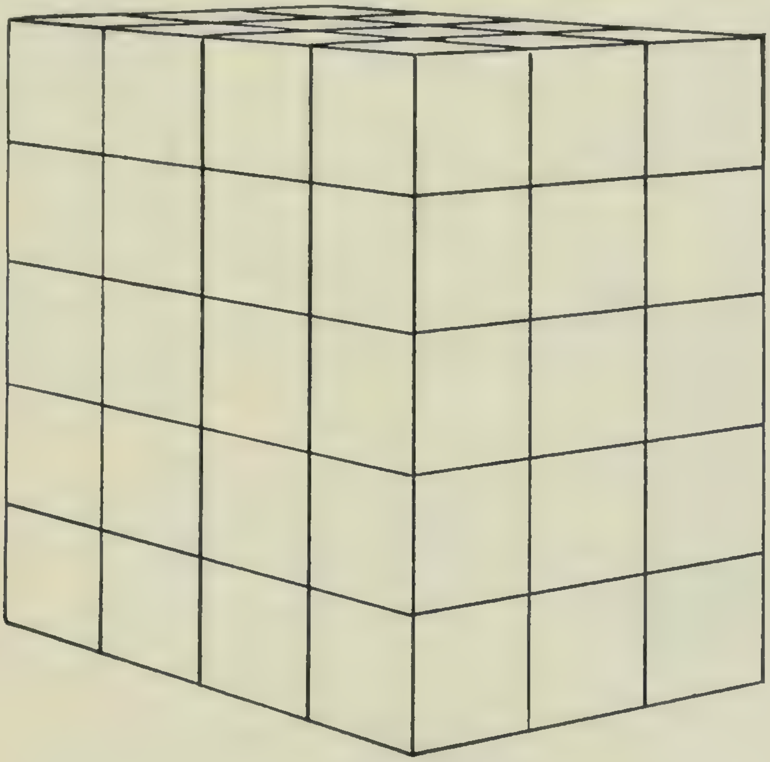

Fig. 285.

Give in centimetres (or inches) the length, width and height of the solid. Knowing these numbers, how would you find the volume of any rectangular solid?

How to use a graduated cylinder.

In the kitchen, a glass measuring cup is used when a certain volume of liquid or flour is required. The graduated glass cylinder (Fig. 286) of the laboratory is employed in a similar manner.

Examine the graduations on a measuring cylinder. Pour in some water and observe the curvature at the surface; this is known as the meniscus curve. When finding the volume of the liquid, the reading at the bottom of the curve should be taken. Where should the eye-level be? What error will be introduced if this precaution is not observed? When taking the reading, is it of assistance to hold a piece of white paper behind the cylinder?

Comparison of two methods of finding the volume of a regular solid.

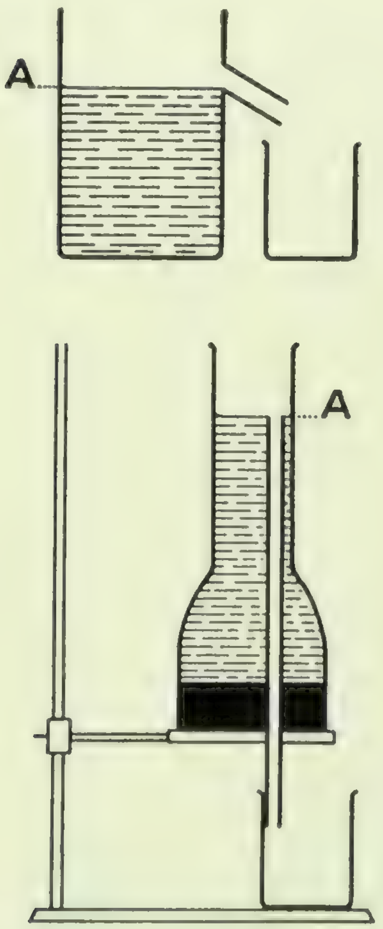

Fig. 287.

Upper figure — Overflow can and catch bucket.
Lower figure — Lamp chimney device. (A is the water level before the solid is placed in the container.)

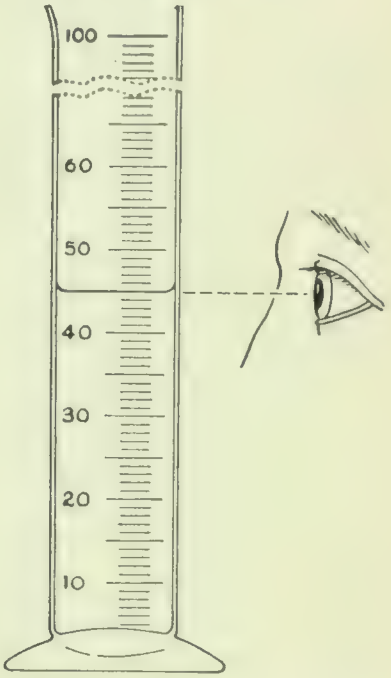

Fig. 286. How to obtain the volume of a liquid in a graduated cylinder.

(i) By measurement and calculation, obtain, the volume in cubic centimetres of a small rectangular piece of metal.

(ii) Pour some water into a graduated cylinder and find its volume. Lower the rectangular piece of metal into the water, being careful to avoid splashing. Why has the water level changed? How could you find the volume of the metal?

Compare the results obtained by the two methods of procedure.

The volume of a solid which floats.

Obtain a rectangular piece of wood small enough to float in the graduated cylinder.

Find its volume by measurement and calculation.

Devise and try two methods by which you could use the cylinder in obtaining the volume of the wood.

Compare the results with that found by measurement and calculation.

To find the volume of a solid too large to fit into the cylinder.

Using the overflow can, or the lamp chimney device, (Fig. 287) and the graduated cylinder how would you find the volume of a solid which could be placed in the former but not in the latter?

MEASUREMENTS OF MASS.

The chemical balance.

The invention of the chemical balance gave scientific research an extraordinary impetus. Although the school balance lacks the refinements of more expensive instruments, when properly treated it is capable of considerable accuracy.

In order to use the balance intelligently it is necessary to know something of its construction. You will notice that when the handle H is turned to the left, as in Fig. 288, the

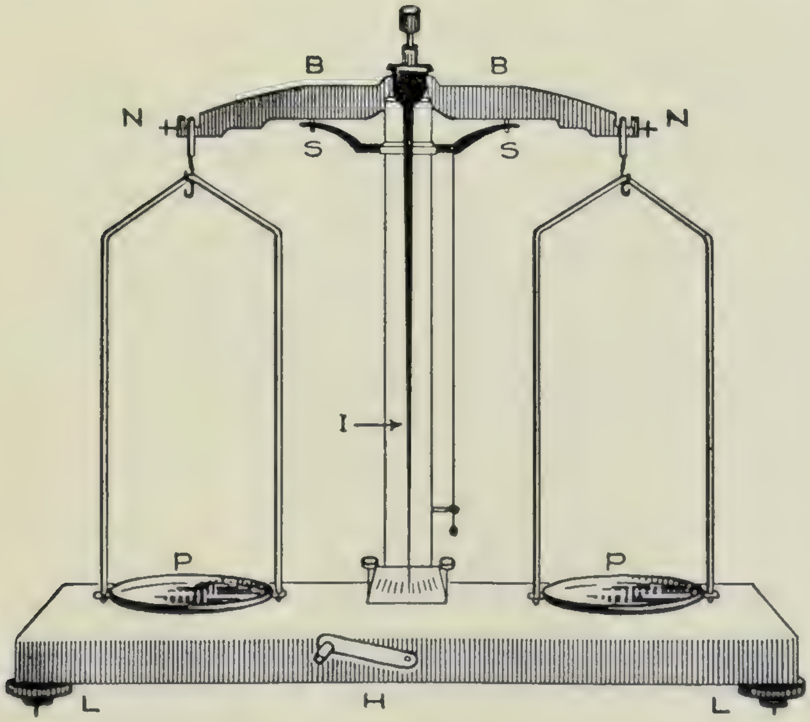

Fig. 288. The chemical balance.

beam BB does not swing; in this position of rest it is supported by the screws marked S.

When the handle is turned to the right, a rod moves upward through the hollow central column and raises the beam above the screws. Now, the agate or steel 'knife-edge' at the middle of BB rests on a surface of one or other of these two hard substances and, if the balance is in adjustment, the beam swings freely. Attached to the beam is a pointer I which moves back and forth across the little scale. Observe if the pointer swings the same distance on each side of the central graduation.

Turn the handle to the left again and notice how the scale-pans P and P are supported. Examine the notches in the stirrups and see how they rest on knife-edges near the end of the beam. The three knife-edges to which we have referred reduce friction. If the beam did not swing easily, the balance would not be sensitive; if the pans did not move freely, they might hang slightly to the right or left of the vertical line and thus cause inaccuracy. It is important that the knife-edges be not abused or given more wear than is necessary.

The 'weights'.

Examine the box of 'weights'. (If you continue to study science you will learn why the term 'masses' should be used here instead of 'weights'.) Why are the masses less than one gram made of the light metal aluminium? You will notice that the largest of these is 500 milligrams, i.e. .5 of a gram and that the smallest is 10 milligrams, or .01 of a gram.

The weights supplied, namely,

500,	200,	200,	100
50,	20,	20,	10
5,	2,	2,	1
.5,	.2,	.2,	.1 grams

may be combined so as to give any weight up to the limit of the box.

Adjustment of the balance.

Adjust the screws L and L until the plumbline indicates that the balance is level.

Turn the handle to the right and watch closely the movement of the pointer across the scale. Screw one of the nuts N and N inward or outward until the pointer travels equal distances on each side of the zero graduation. (You may regard N and N as two boys on a teeter.)

Precautions to be observed when using balance.

1. Keep the balance clean and dry.

2. Sit directly in front of it and place the box of weights in the most convenient position .

3. Put substances to be weighed in a container and not on the unprotected pan. Weigh the empty container and find the weight of the substance by subtraction.

4. Allow hot substances to cool before weighing them.

5. Do not place on a pan or remove from it either a weight or the object to be weighed while the beam is swinging. First turn the handle to the left and thus remove the beam from the knife-edges.

6. Turn the handle gently to avoid jarring the knife-edges.

7. Place the object, the weight of which is desired, in the left-hand pan.

8. Do not lift the weights with the fingers; use the forceps supplied.

9. Set the object to be weighed in the middle of the pan; place the larger weights in the same position in their pan.

10. When weighing, start with a weight which you think may be

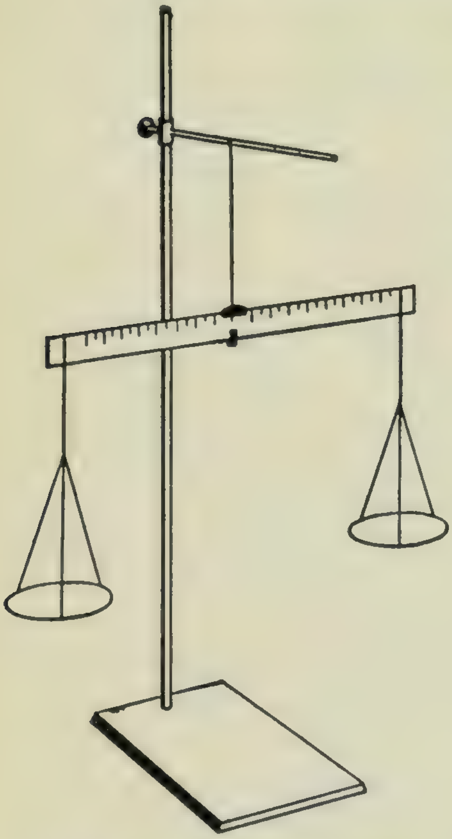

Fig. 289. An improvised balance.

too heavy. If it is too heavy, remove it and try the next.

11. There are only two places where the weights should be set down—on the pan, or in the box.

12. Total the weights before removing them from the pan. Record this amount in your notebook and check its accuracy when returning the weights to their box.

13. When finished with the balance, see that the beam is in the position of rest. Remove the pans from their knife-edges and close the weight box.

How the balance may be used in finding area.

Find the area of a rectangular piece of cardboard by measurement and calculation. Weigh (a) the cardboard, (b) a piece of the cardboard one square inch in area. From the two weights calculate the area of the original rectangle. Compare the result with that found by measurement and calculation.

Determine the area of an irregular piece of cardboard by using the balance.

Metric Units of Length.

(1 millimetre	=			0.001	metre)
10 millimetres	=	1 centimetre	=	0.01	metre
10 centimetres	=	1 decimetre	=	0.1	metre
10 decimetres	=	1 METRE			
10 metres	=	1 dekametre			
10 dekametres	=	1 hectometre	=	100	metres
10 hectometres	=	1 kilometre	=	1000	metres

Metric Units of Volume.

(1 millilitre	=		=	0.001	litre	=	1 cu.cm.)
10 millilitres	=	1 centilitre	=	0.01	litre	=	10 cu.cm.
10 centilitres	=	1 decilitre	=	0.1	litre	=	100 cu.cm.
10 decilitres	=	1 LITRE				=	1000 cu.cm.
10 litres	=	1 dekalitre					
10 dekalitres	=	1 hectolitre	=	100	litres		
10 hectolitres	=	1 kilolitre	=	1000	litres		

Metric Units of Mass.

(1 milligram	=		=	0.001	gram)
10 milligrams	=	1 centigram	=	0.01	gram
10 centigrams	=	1 decigram	=	0.1	gram
10 decigrams	=	1 GRAM			
10 grams	=	1 dekagram			
10 dekagrams	=	1 hectogram	=	100	grams
10 hectograms	=	1 kilogram	=	1000	grams

Miscellaneous Relationships.

1 inch	=	2.54 cm.	1 cm.	=	0.3937 inches
1 mile	=	1.609 km.	1 metre	=	39.37 inches
1 cu. in.	=	16.387 cu.cm.	1 km.	=	0.62 (or ⅝) mile
1 gallon	=	4.546 litres	1 litre	=	1.76 pints
1 pound	=	454 grams	1 kg.	=	2.2 pounds
1 cubic foot of water	=	62½ pounds			
1 gallon of water	=	10 pounds			

Density.

If you requested the average person to compare lead and cork, at once he would point out that one was much heavier than the other. Should you object to this, saying that a pound of cork and a pound of lead weighed precisely the same, he would likely answer that a pound of cork is much bulkier than a pound of lead. Finally, both of you would agree that if the *same volume* of the two substances were taken the lead would weigh more than the cork. In scientific language, we say that lead is denser than cork.

In order to compare different substances in this respect, we take one cubic foot (or one cubic centimetre) of each. *The mass of this unit volume is the density of the substance.* For example, the density of granite is 169 pounds per cubic foot, the density of gasoline is 42 pounds per cubic foot, etc.

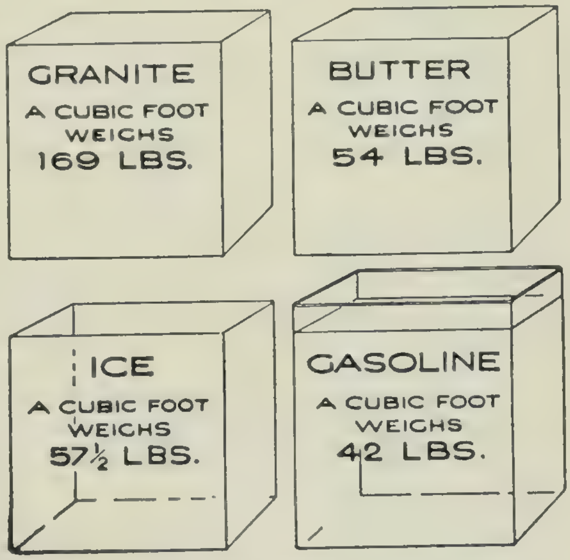

Fig. 290. Density is the mass of unit volume.

If we were to make our measurements in the metric,, instead of the British, system the numbers representing the density would be different. In the metric system, granite has a density of 2.7 grams per cubic centimetre; gasoline, a density of .67 grams per cubic centimetre. (You will notice, however, that 169 is as many times as great as 42 as 2.7 is as great as .67.)

To find the density of a rectangular solid.

Use a rectangular solid the volume of which you have already found by measurement and calculation. Find the mass of the body and calculate its density in the metric system.

To find the density of water.

What objections may be raised to finding the mass of a single cubic centimetre of a liquid? Take a reasonably large volume of water, weigh it and then find its volume by means of a graduated cylinder. Calculate the density of water.

What is the weight of a litre of water?

It did not happen by accident that a cubic centimetre of water weighs a gram. When the length of the metre was obtained, in the way we described previously, the length of the centimetre was, of course, settled; from the centimetre was derived the cubic centimetre. The mass of a cubic centimetre of water at 4° C. was *called* a gram.

How do expansion and contraction affect the density of water?

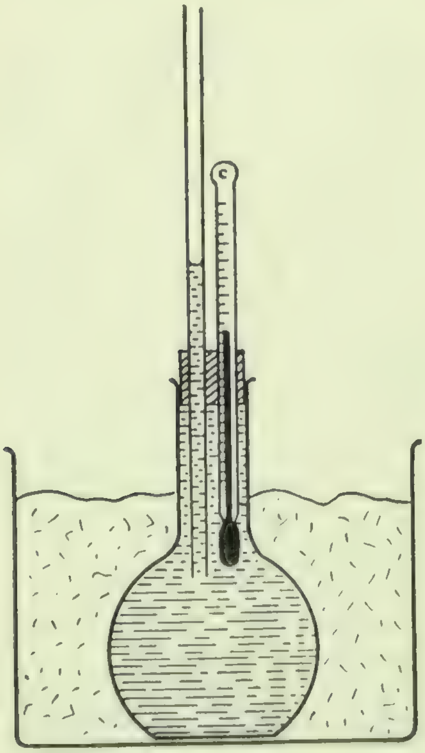

Fig. 291. Experiment to illustrate how water behaves when it is cooled.

Alert pupils will point out that water expands when heated and contacts when cooled, and so a cubic centimetre at any temperature will have a different volume when the temperature changes. This is quite true; in our experiment we neglected the influence of changes in temperature.

Study of the effect of heat on the volume of water.

Fit a flask, completely filled with coloured water at room temperature, with a cork through which pass a Centigrade thermometer and a length of glass tubing, (Fig. 291). It is desirable that the tube should be of narrow bore. Surround the flask with crushed ice, or better still, a mixture of ice and salt. Note the temperature and also the level of the coloured water in the tube. When the temperature falls to 7° C., watch both thermometer and water-level continuously. Do you observe any peculiarity in the behaviour of the water? At what temperature did this strange behaviour begin. When the temperature falls to 0° C., place the flask in luke-warm water and observe the water-level and temperature as the water is heated.

When water at room temperature is cooled, it behaves for a time like other liquids by contracting. However, at 4° C. it attains its least volume, and, strangely enough, expands as it is cooled from 4° C. to 0° C. The reverse occurs when ice-cold water is heated. It contracts as the temperature rises from 0° C. to 4° C., then it expands.

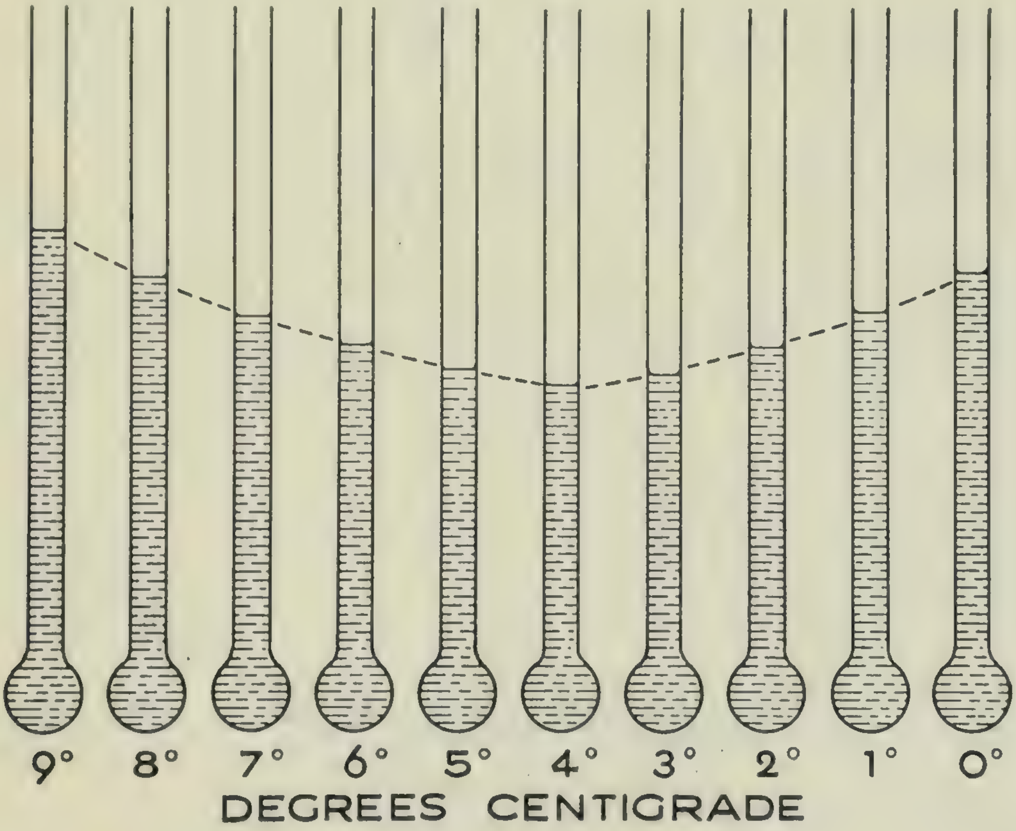

Fig. 292. The strange behaviour of water when it is cooled.

Hence, a given mass of water attains its least volume at 4° C.

(Because your flask expanded when heated and contracted when cooled, and because *all* the water in the flask would not be at any particular temperature registered on the thermometer, since it was not kept stirred, your results would not agree with those obtained in much more careful experiments.)

If we start with a cubic centimetre of water at say 50° C. and cool it, the *mass* is unaltered but the *volume* becomes less and less. At 4° C. the latter is least. Hence, less than one cubic centimetre at 4° C. would have the same mass as a cubic centimetre at 50° C. Clearly, a cubic centimetre of water at 4° C. would weigh more than a cubic centimetre at temperatures above or below 4° C. In other words, water has its maximum density at that temperature. When we were finding the density of water, we ignored the temperature. Indeed, we had no other choice because the ordinary balance is not sensitive enough to detect the difference in the mass of a few hundred cubic centimetres at 20° C. and that of the same volume at, say, 10° C.

Importance in nature of the strange expansion of water.

Let us imagine the freezing of a pond on a cold night in early winter. As the upper part of the water cools, it contracts. Consequently, each cubic foot is heavier than the same volume of the warmer underlying liquid. A current is set up. The colder (and heavier) water sinks to the bottom and pushes up the warmer. This continues until the water at the bottom has a temperature of 4° C. Now, each cubic foot of the deepest water has its greatest mass and so there is no tendency for it to rise upward. Eventually, all the water in the pond attains 4° C. When the surface water cools to 0° C., it remains at the top and ice forms there. Since ice has a

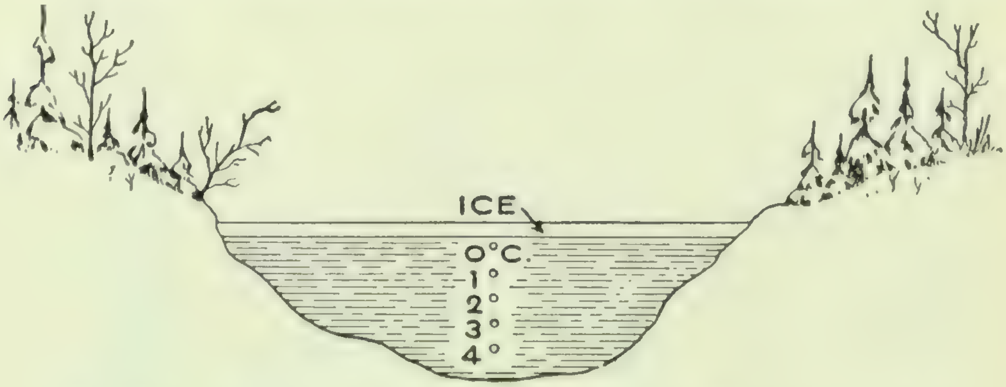

Fig. 293. A pond in winter. Why is the warmest water at the bottom?

greater volume than the water from which it is derived, its density is less than that of the liquid; consequently, it floats. When a certain thickness of ice is attained, the protective 'blanket' prevents the pond from freezing to the bottom unless it is very shallow.

It is not difficult to picture what would happen if water like other liquids, were heaviest at its freezing point. Ice would form first at the bottom. Anchored to the bottom, it would remain there, and would add to its thickness in the upward direction. Lakes, rivers and seas in the colder parts of the world would soon be completely converted to ice; in summer, melting would be confined to a very small depth. Our climate would be much colder and aquatic life, as we know it, would be non-existent.

Describe how a pond would freeze if ice were heavier than water. (Assume that the pond-water, like the water with which we are familiar, is heaviest at 4° C.)

The density of mercury[1]

The liquid metal, mercury, is much used in scientific work. Frequently it is necessary to know the density of the liquid.

(i) Find the mass of a clean vial and its cork. Hold the vial over a dish, and pour in mercury. Tap the vial in order to get rid of air bubbles. Still holding the little bottle over the dish, insert the cork. See that there is no air between the cork and liquid. Now weigh the vial and its contents and by subtraction obtain the weight of the mercury alone.

After removal of the mercury, pour in water to the same level. Find the volume of this water by means of a graduated cylinder. Now calculate the mass of one cubic centimetre of the metal.

Accurate experiments inform us that the density of mercury is 13.6 grams per cubic centimetre. How does your result compare with this figure? At what stage in your experiment was error most likely to enter?

(ii) A much higher degree of accuracy is attained when weighing than when finding volumes. It is possible to find the density of mercury by use of the balance alone.

Fill the vial with water, insert the cork and obtain the total mass. Find the weight of the water alone, making use of the fact that one gram of water occupies one cubic centimetre, determine the volume of water and, hence, that of the mercury.

---

[1] Optional.

Knowing the mass and volume of the mercury, calculate its density. Compare your answer with that obtained in the previous experiment and with the correct amount already stated.

Table of Densities.

Substance	Pounds per cubic foot	Grams per cubic centimetre
Gasoline	42	.67
Maple wood	39-47	.62-.75
Butter	54	.86
Ice	57	.92
Water (at 4° C.)	62.4	1.00
Milk	64	1.029
Sea-water	64	1.03
Human body	67	1.07
Limestone	167-172	2.68-2.76
Copper	558	8.94
Lead	708	11.34
Mercury	848	13.6
Gold	1207	19.34

Exercises:

(1) State some arguments for and against the everyday use of the Metric System in Canada.

(2) The Imperial Standard Yard is defined as the distance between two marks on a certain bronze bar at 62° F. The Imperial Gallon is defined as the volume of 10 pounds of water at 62° F. Explain why the temperature is specified.

(3) A ball of wool is squeezed tightly. What is the effect on (a) the mass, (b) the volume, and (c) the density?

(4) How is the volume affected when water is converted into ice? Show that ice must have a density less than one gram per cubic centimetre.

(5) What is the mass of 8 gallons of gasoline? (A gallon of water weighs 10 pounds.)

(6) What is the volume in cubic feet of a boy who weighs 100 pounds?

(7) Why does cream rise to the surface of milk instead of sinking to the bottom or remaining mixed?

(8) How does the density of watered milk compare with that of the unadulterated product?

(9) How would the density of milk be affected if some of the cream were removed?

(10) Some milk was both skimmed and watered. Explain why the density did not differ greatly from that of a normal sample.

(11) When heated from 41° F. to 95° F., a cubic foot of water expands 8.6 cubic inches. If the mass of a cubic foot of water at the lower temperature is 62.41 pounds, calculate the mass of a cubic foot at the higher.

GLOSSARY

Key to the pronunciation:

ā hate	ē me	ī line	ō note	ū tune
ȧ car	e men	i pin	o not	u run
a mat	ė her		ö noon	ü pull
ä tall				

Accent is indicated by the signs′ and ″.

Alimentary canal (al i men′ ta ri): [Lat. *alimentum,* nourishment]: the food passage which extends from the mouth to the anus.

Amoeba (a mē′ ba), plural **Amoebae** (a mē′ be): [Gk. *amoibe,* change]: an animal which consists of a single cell.

Aneroid (an′ er oid); [Gk. *a,* not; *neros,* wet]: a barometer in which a liquid is not used.

Anhydrous (an hī′ drus); [Gk. *an,* without; *hydor,* water]: a term applied to substances deprived of some or all the water they could contain.

Annual [Lat. *annus,* a year]: a term applied to plants which live for approximately a year.

Anther (an′ thėr); [Gk. *antheros,* flowery]: the part of a stamen in which the pollen is developed.

Aquarium (a kwā′ ri um); [Lat. *aqua,* water]: a tank containing water in which living plants and animals are kept.

Artesian (ar tē zhan); [From *Artois,* a part of France where, it is said, this type of well was used first]: name given to wells in which water is forced up to, or above, the surface of the ground without the aid of a pump.

Bacterium (bak te′ ri um); plural **Bacteria** (bak te′ ri a); [Gk. *bakterion,* a little stick]: a minute plant visible only under strong magnification.

Barge (bärj); [Fr., from late Lat. *barga,* bark]: a harvester stacker used in many parts of Alberta.

Barometer (ba rom′ e ter); [Gk. *baros,* weight; *metron,* measure]: an instrument used in measuring the pressure of the atmosphere.

BASALT (ba sawlt'); [Lat. *basaltes,* an African word]: an igneous rock of greenish black colour.

BIENNIAL (bī en' ni al); [Lat. *biennium,* a space of two years]: a plant that dies after approximately two years, in the second of which seed is produced for the first time.

BRONCHUS (brong' kus), plural BRONCHI (brong' kī): one of the two tubes to which the windpipe leads.

BUD: a structure which contains the beginnings of leaves, or flowers, or leaves and flowers, and also the very short stem to which they are attached.

BULB: a structure consisting of a disc-like stem attached to which are leaves, or the bases of leaves, swollen with stored food.

CALORIE (kal' ō ri); [Lat. *calor,* heat]: the quantity of heat necessary to raise the temperature of one gram of water one centigrade degree; the large Calorie (frequently spelled with a capital 'C') is a thousand times this quantity.

CALYX (kī' liks); [Gk. *kalyx,* husk]: protective flower-leaves, generally greenish in colour.

CAMBIUM (kam' bi um); [Lat. *cambire,* to exchange]: a very thin layer of cells between the wood and soft bark of dicotyledonous stems, to the activity of which increase in diameter is due.

CAPILLARY (kap' i lar i); [Lat. *capillus,* hair]: small and fine; hair-like; possessing a very small bore.

CARBOHYDRATE (kȧr bō hī' drāt): a member of a group of substances which includes sugars and starches; these contain carbon, hydrogen and oxygen.

CARNIVOROUS (kȧr' niv' ō rus): flesh-eating.

CARPEL (kȧrp' el); [Gk. *karpos,* fruit]: part of a pistil.

CATCHMENT: a basin or area from which water flows.

CELL [Lat. *cella,* a small room or compartment]: any small compartment; one of the microscopic units of which plants and animals are built up.

CELLOPHANE: transparent cellulose sheets.

CELLULOSE (sel' lū lōs): the material composing the walls of plant cells.

CENTIGRADE (sen' ti grād); [Lat. *centum,* hundred; *gradus,* a degree]: a scale of temperatures in which the freezing point of water is 0, and the boiling point 100.

Chinook: a wind which is one of the characteristic features of the climate of Alberta and usually occurs with strong southwest and west winds.

Chlorophyll (klō′ rō fil); [Gk. *chloros*, green; *phyllon*, leaf]: the substance which gives plants their green colour.

Chrysalis (kris′ a lis); [Gk. *chrysos*, gold]: the pupal stage of moths, butterflies and other insects.

Chlorine (klo′ rēn); [Gk. *chloros*, greenish-yellow]: a greenish-yellow gas.

Clipper: a sailing vessel with very sharp lines and great spread of canvas; recently applied to certain aeroplanes.

Combustion (kom bust′ yun); [Lat. *combustum, comburere*, to burn]: the act of burning; the union of an inflammable substance with oxygen.

Composite: made up of various parts; Compositae, plants in which the so-called flower is a head of many little flowers or florets.

Condiment (con′ diment); [Lat. *condimentum, condire*, pickle]: that which is eaten along with food to give it a pleasing taste.

Constellation (kon ste lā′ shun); [Lat. *con*, with or together; *stella*, star]: a group of stars to which a name has been given.

Convection [Lat. *convehere*, to convey]: the conveyance of heat through liquids and gases by means of currents.

Corolla (ko rol′ a); [Lat. *corolla*, a little crown or garland]: a set of flower-leaves within the calyx.

Corrugate (cor′ rugate); [Lat. *corrugatus*, wrinkled]: to form or shrink into groves or wrinkles.

Cortex [Lat. *cortex*, bark]: that part of a root or stem between the epidermis and the fibro-vascular bundles.

Crystal (crys′ tal); [Gk. *krystallos*, ice]: a kind of stone with regular sides and angles.

Curd (kērd); a substance formed by the action of acids on milk; curdle, to thicken.

Cuticle [Lat. *cutis*, skin]: the thin skin of a leaf or stem.

Cyclone (sī′ klōn); [Gk. *kyklos*, a circle]: a region of low pressure; also frequently used in reference to hurricanes and typhoons.

Density [Lat. *densus*, thick]: the mass of one cubic centimetre, or of one cubic foot; in general, the quality of being compact or close.

DICOTYLEDON (dī′ kot i lē″ don); [Gk. *di*, two; *kotyle*, a cup]: a plant with two seed-leaves and with its fibro-vascular bundles regularly arranged.

DIGESTION: the changes which food undergoes before absorption occurs.

DILUTE (di lūt′); [Lat. *diluere*, to dissolve]: reducing the strength of a solution by adding liquid.

DISTILLATION [Lat. *destillare*, to drip, trickle]: the process of converting a liquid into vapour and then condensing the latter.

DOMESTICATE [Lat. *domus*, a home]: to tame; to remove from a wild state.

DUFF (duf): a vegetable growth accumulated in forest ground.

ECLIPSE (e klips′); [Gk. *ekleipein*, to leave out]: a partial or complete shutting off of light from the sun, moon, or other heavenly body.

EFFERVESCE (ef fēr ves′): [Lat. *fervescere*, to boil]: to boil up; to bubble and hiss by giving off gas.

ELECTRODE (e lek′ trōd): either of the poles or terminals of a source of electricity.

EMBRYO (em′ bri ō): a plant or animal in its early stages of development.

EPIDERMIS (ep i der′ mis); [Gk. *epi*, upon; *derma*, skin]: (in botany) the outer layer of cells in roots, stems and leaves.

EQUINOX (ē′ kwi noks); [Lat. *aequus*, equal; *nox*, night]: the dates on which day and night are of equal length; the vernal (or spring) equinox is about March 21, the autumnal equinox, about September 23.

EROSION (ē rō′ zhon); [Lat. *e*, out of, away from; *rodere*, to gnaw]: the breaking down of rock or removal of soil by agents such as ice, water and wind.

EVAPORATION [Lat. *e*, out of; *vaporare*, to steam, smoke]: the process of change from liquid to gas.

FAHRENHEIT (fär′ en hīt); [Name of experimenter] a scale of temperatures in which the freezing point of water is 32, and the boiling point 212.

FAT: a member of a group of substances which contain carbon, hydrogen and oxygen; the hydrogen and oxygen are not present in the same proportion in fats and carbohydrates.

Fertilization (fĕr′ til i zā″ shon); [Lat. *fertilis*, fruitful]: (in flowering plants,) the union or fusion of two minute structures, one developed in a stamen, the other in a pistil, essential for the formation of seed.

Fibro-vascular bundle (fī brō vas′ kū lĕr); [Lat. *fibra*, fibre; *vasculum*, a small dish or vessel]: groups of cells, some of which are strengthening fibres, and others, ducts for conveyance of water or manufactured food.

Filament (fil′ a ment); [Lat. *filum*, a thread]: (in botany,) the thread-like part of a stamen.

Filtrate [Lat. *filtrum* or *feltrum*, felt or wool, once used in straining]: the liquid obtained after filtration.

Filtration: the separation of insoluble substances from a liquid by passing it through paper, cloth, sand, etc.

Floret [Lat. *flos, floris*, flower]: one of the little flowers in a 'head'.

Fossil (fos′ sil); [Lat. *fossus*, dug]: the hardened remains of animals or plants found in rocks.

Friction (frik′ shōn); [Lat. *fricare*, to rub]: the rubbing of one body against another.

Fruit: (in botany,) the ripened ovary and its contents; in some cases, e.g., the apple, the greatly enlarged receptacle may be part of the fruit.

Germ [Lat. *germen*, bud]: a name popularly applied to very small plants and animals; the word is used in a number of other senses.

Gland: a group of cells which make and release a substance of use to the body, e.g. saliva; the emotions, growth, digestion, etc., are influenced by substances released from glands; the liver is the largest gland in the body.

Gravitation (grav i tā′ shun): the power that makes bodies fall towards each other or to the ground.

Head: (in botany,) a cluster of little flowers or florets, e.g. the blossom of dandelion, sunflower, Canada thistle.

Herbaceous plant (hėr bā′ shus); [Lat. *herba*, grass, herb]: a plant which dies down to the root when frost comes.

Hibernate (hīber′ nate); [Lat. *hiems*, winter]: to pass the winter (in sleep).

HORMONES: chemical substances secreted by the ductless glands in the animal body, which tend to regulate body processes.

HOST: (in biology,) a plant or animal on, or in, which other plants or animals live and, usually, from which they derive nourishment. (See PARASITE.)

HUMIDIFICATION (hū mid′ i fi kā″ shun); [Lat. *humere*, to be moist]: the regulation of the relative humidity of a house.

HUMIDITY (hū mid′ i ti): moisture, dampness. Relative Humidity is the percentage the quantity of water vapour actually present in a given space is to the quantity necessary to saturate that space at the same temperature.

HYDROGEN (hī′ drō jen); [Gk. *hydor*, water; *gennao*, produce]: a colourless gas which, along with oxygen, is obtained when water is broken up by the electric current; it is the lightest substance and forms an explosive mixture with air or oxygen.

HYGROMETER (hī grom′ e ter); [Gk. *hygros*, wet; *metron, measure*]: an instrument used in finding the relative humidity.

ILLUMINATION (il lū mi nā′ shun); [Lat. *illuminatus*, lit up (*lumen*, light)]: supply of light.

IMPERVIOUS (im pėr′ vi us); [Lat. *in*, not; *pervius*, passable, affording a passage]: a term used to describe something which will not permit passage through it; applied to a layer of rock through which water cannot pass.

INFLORESCENCE (in flō res′ ens); [Lat. *inflorescere*, to begin to blossom]: the manner in which flower clusters are arranged on the stem.

INSECTIVOROUS (in sek tiv′ o rus); [Lat. *insectum*, insect; *vorare*, devour]: feeding on insects.

INVOLUCRE (in vō lū′ kër); [Lat. *involucrum*, a covering, wrapper, envelope]: a circle of bracts such as those of the dandelion flower.

ISOBAR (ī′ sō bȧr); [Gk. *isos*, equal; *baros*, weight]: a line on the map joining places whose atmospheric pressures, corrected for height above sea-level, are the same.

JUTE (jöt): fibre from an Indian plant used in the manufacture of bags, mats, and coarse carpets.

LARVA (lȧr′ va), plural LARVAE (lȧr′ vē): the young of an insect which has a complete metamorphosis; a grub, caterpillar or maggot.

Larynx (lar′ ingks) : the ‘Adam’s apple’ or voice-box at the upper end of the windpipe.

Legume (leg′ ūm) ; [Lat. *legumen*, pulse] : a group of plants to which the pea, bean, clover, and alfalfa belong; the fruit of plants of this group.

Lime: the term ‘lime’ is applied to a number of substances; it may refer (1) to limestone, (2) to quick lime, (3) to slaked lime, (4) to limewater.

Luminous (lū′ mi nus) : giving out light.

Lunar (lö′ nar) ; [Lat. *luna*, the moon] : pertaining to the moon.

Mammal (mam′ mal) ; [Lat. *mamma*, the breast] : an animal that gives milk to its young.

Marsh : low-lying land partly covered with water.

Medicinal (me-dis′ i nal) : used in medicine.

Medullary rays (mē dul′ la ri) ; [Lat. *medulla*, marrow, pith] : cells which connect the inner and outer parts of woody stems; as well as serving as channels for the distribution of food they are often employed for the storage of it.

Membrane (mem′ brān) ; [Lat. *membrum*, a member] : a thin skin forming the covering of some part or organ of the body of an animal or a plant.

Metamorphosis (met a mor′ fō sis) ; [Gk. *meta*, denoting, change; *morphe*, form] : a conspicuous change in the form of an animal during its development, e.g. the changes in a butterfly and frog.

Meteorology (mē te ēr ol′ ō ji) : the science which describes the changes in the air, especially weather, wind, etc.

Micropyle (mī′ krō pīl) ; [Gk. *mikros*, small; *pyle*, gate] : the little opening in the coat which surrounds an ovule, through this aperture the pollen-tube passes.

Microscope [Gk. *mikros*, small; *skopein*, to view] : an instrument by which we are enabled to see very small objects.

Molecule (mol′ e kūl) : the smallest particle of a substance that can exist and possess all the properties of the substance.

Mongoose (mon′ gös) : a small animal that is able to kill venomous snakes unharmed; common in India.

MONOCOTYLEDON (mon′ ō kot i lē″ don); [Gk. *monos*, single; *kotyle*, a cup]: a plant with one seed-leaf and with its fibro-vascular bundles lacking definite arrangement.

MONSOON (mon sön′); [Arabic, *mausim*, a time or season]: a wind of the Indian Ocean which from April to October blows from the south-west, and during the rest of the year, from the north-east; similar winds in any region.

MOULD (mōld): a member of a group of plants which lack chlorophyll and live on dead plant or animal matter.

MUCK: damp, decaying matter.

MULCH: half-rotten straw, litter, etc., used to protect the roots of trees, plants, etc.; a term used when the top layer of soil is loosened to prevent evaporation of soil water.

NARCOTIC (när kot′ ik); [Gk. *narke*, stupor, numbness]: a substance which in small amounts gives relief from pain and induces sleep, but, in excess, may be fatal.

NECTAR [Gk. *nektar*, the drink of the gods]: the sugar solution produced by many flowers.

NITROGEN (nī′ trō jen); [Gk. *nitron*, nitre; *gennao*, produce]: the most plentiful gas in the atmosphere, of which it forms about eighty per cent by volume.

NYMPH (nimf): (in biology) the young of insects, such as grasshoppers and dragonflies, which have an incomplete metamorphosis.

OESOPHAGUS (ē sof′ a gus): the gullet; the part of the food canal between the pharynx and the stomach.

OFFAL: the waste part of an animal killed for food; anything worthless.

ORBIT (or′ bit): the path along which a heavenly body travels in its revolution.

ORGANISM (or′ gan izm): any living plant or animal.

OSMOSIS [Gk. *osmos*, pushing]: the passing of soluble substances through a membrane.

OVARY: the case in which the ovules are contained.

OVULE (o′ vūl); [Lat. *ovum*, an egg]: the structure which, after fertilization, develops into a seed.

Oxidation (ok si dā′ shun): the uniting of a substance with oxygen. (This is not a complete description.)

Oxygen (ok′ si jen): a gas necessary for respiration and combustion and forming about twenty per cent of the atmosphere by volume.

Palisade [Lat. *palus*, stake, pole]: a fence made of upright stakes; the regular layer of cells under the upper epidermis of a leaf.

Pappus [Gk. *pappos*, down]: the hairy growth on the fruits of dandelion, sow thistle, and other plants belonging to the same group.

Parasite [Gk. *para*, beside; *sitos*, food]: a plant or animal that lives in or on another organism and obtains its food from it.

Perennial [Lat. *per*, through; *annus*, a year]: a term applied to a plant that lives for a number of years.

Petal [Gk. *petalon*, a leaf]: one of the parts of a corolla.

Phloem (flō′ em); [Gk. *phloios*, bark]: cells situated in the outer part of a fibro-vascular bundle, and used as ducts for the downward movement of dissolved food.

Photosynthesis (fō′ tō sin″ the sis); [Gk. *phos*, light; *synthesis*, a putting together].

Pistil [Lat. *pistillum*, a pestle]: the part of a flower which contains the ovules.

Pollen (pol′ en); [Lat. *pollen*, fine flour]: the little grains formed in the anthers and essential for fertilization of the ovules.

Pollination: the transference of pollen from anther to stigma.

Pore [Gk. *poros*, a passage]: a small opening.

Porous: provided with numerous pores.

Precipitate [Lat. *praeceps*, headlong]: a finely-divided solid settling to the bottom of a liquid.

Proboscis (prō bos′ sis); [Gk. *proboskis*, a trunk]: the tube possessed by certain insects which fits them for sucking or for piercing and sucking.

Protein (prō′ te in): a member of a class of substances which contain carbon, hydrogen, oxygen, nitrogen, sulphur and, frequently, phosphorus; the protoplasm of plant and animal cells consists mainly of proteins.

PROTOPLASM (prō' to plazm); [Gk. *protos*, first; *plasma*, form, mould]: a colourless substance, resembling the white of eggs, found in plant and animal cells; it has been called "the physical basis of life".

PUPA (pū' pa), plural PUPAE (pū' pē): the third stage of an insect with a complete metamorphosis.

QUININE (kwin' īn); [Peruvian-Indian *quina*, bark]: a substance used in medicine.

RAYON: artificial silk manufactured from wood pulp.

RECEPTACLE: the enlarged part of the stalk at the base of the flower.

RESPIRATION [Lat. *re*, again; *spirare*, to breathe]: the process in which organisms obtain oxygen and release waste gases.

RHIZOME (rī' zōm): an underground stem which frequently bears marked resemblance to a root.

SALIVA (sa lī va): the liquid produced by certain glands in the mouth.

SANDSTONE: a rock formed by the cementing together of grains of sand.

SATURATION [Lat. *satur*, full, sated]: the state of being filled or soaked; the condition of a solution which cannot dissolve any more of a substance.

SEPAL (sē' pal): one of the parts of which a calyx consists.

SEPTIC [Gk. *sepein*, to make putrid]: causing decay.

SHALE [Germ. *schale*, a shell, a thin layer]: a rock which consists of hardened clay.

SOLAR (sō' lar); [Lat. *sol*. the sun]: pertaining to the sun.

SOLUTION (in chemistry,) the uniform mixture formed when certain solids are placed in certain liquids, or a gas in a liquid, or a liquid in a liquid.

SPECTROSCOPE (spek' trō skōp): an optical instrument for forming and examining spectra.

SPECTRUM (spek' trum): the coloured and other rays of light separated by a prism and exhibited on a screen.

STAMEN (stā' men); [Lat. *stamen*, the warp or foundation thread in weaving]: the structure which produces pollen.

Stereoscope (ster′ e ō skōp): an optical instrument by means of which two pictures appear as one with the effect of solidity.

Stigma: the moist, roughened end of the style where pollen lodges.

Stoma (stō′ ma), plural Stomata (stō′ ma ta); [Gk. *stoma*, month]: a very small opening in a leaf or stem.

Stratum (strā′ tum), plural Strata (strā′ta): a layer of soil or rock.

Sublimation (sub li mā′ shon); [Lat. *sublimo*, to raise, elevate]: the conversion by heat of certain solids directly to gas, and then, by condensation of the gas, to the solid form again.

Subterranean (sub te rā′ ne an); [Lat. *sub*, under; *terra*, earth]: underground.

Testa [Lat. *testa*, a shell, hard covering]: the outer layer of the coat surrounding a seed.

Tincture (tingk′ tūr): solution of any substance.

Tissue (tish′ ū): a group of cells similar in their structure and function.

Trachea (trā′ ke a): the windpipe; a respiratory tube in an insect.

Tuber (tū′ ber): [Lat. *tuber*, a lump, swelling]: a short underground stem swollen with stored food.

Vitamin (vī′ ta min); [Lat. *vita*, life]: one of a group of food constituents which are necessary for health and growth.

Water table: the upper surface of the zone of soil which is saturated with water; the ground water-level.

Weight: the force which the earth exerts vertically downward on all bodies.

Xylem (zī lem); [Gk. *xylon*, wood]: woody cells; the inner part of a fibro-vascular bundle.

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